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Radar, thermal infrared, and panchromatic image collection and analysis

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The addendum to the Multi-Source Image Analysis contract consists of a reference set of simultaneously collected remote sensor data designed to evaluate terrain features. Airborne radar, thermal infrared and panchromatic imagery was collected by the Oregon Army National Guard at the Corvallis, Oregon, test site on 13 and 19 August 1980. Ground teams collected radiant and air temperatures, ground site photographs and soil samples from three traverses through the test area.

SUMMARY

The addendum to the Multi-Source Image Analysis consists of a reference set of simultaneously collected remote sensor data designed to evaluate terrain features. The site for collecting the imagery set is the Corvallis, Oregon area. Airborne imagery (radar, thermal infrared and panchromatic) was collected by the Oregon Army National Guard. Three teams of scientists collected ground information simultaneous with the overflights on August 13, 1980. A second set of images was obtained on August 19, 1980 simultaneous with a LANDSAT overflight. Information from the ground teams included: radiant temperatures, ground site photographs, air temperatures and soil samples. This information was all processed and analyzed for use in the interpretation of the aircraft and satellite imagery.

The test site in the Corvallis, Oregon area includes the Coast Range foothills and the Willamette River Valley. These two physiographic provinces provide a wide range of terrain features for analysis. The foothills of the Coast Range are covered by a series of coniferous trees in the higher areas and deciduous trees and various shrubs in the lower foothills. A gap in the foothills near the Camp Adair State Military Reservation is similar in configuration and physiography to the Fulda Gap area of the Federal Republic of Germany, a potentially strategic location in European defense plans. Where the foothills intersect the valley, numerous small rivers and streams flow eastward toward the Willamette River. Riparian vegetation along these drainage features represent good targets for the radar and panchromatic sensors.

The radar, thermal infrared and panchromatic imagery was interpreted in detail at eight locations. It should be noted that a much more detailed evaluation is possible but is outside the scope of the project. The eight sites were picked as representative of the various urban, mountainous foothill and valley features. Each site includes a number of ground data collection locations. Two visits were made to each location during the ground site investigation. The first visit took place pre-dawn on August 13, 1980 to collect data primarily for use in the interpretation of the thermal infrared imagery. The second visit on the same day took place near the peak of the photographic day. During this second visit photographs were collected and feature identifications were made. Included in the collections were soil samples which were later evaluated for moisture content. This data was used in the evaluation of emissivity differences as determined on the thermal infrared imagery. Spot densitometer measurements were taken from the thermal mapper film at the locations corresponding to the surface collection sites. The soil moisture and density reading were then compared.

The primary results from the interpretation give several clues to the type of imagery that would be most favorable in a terrain analysis study. The panchromatic photography shows the most detail for the majority of features. The crops in the fields can be identified when a calibration source is known. Road types can be identified and land use identification within the urban area is possible. The problem is that good weather during the photographic day is necessary for the collection of this data. With this drawback in mind the detail available on the other two types of imagery becomes much more important. Radar is an excellent sensor for metal detection, especially when corner reflectors are present. Radio transmitting antennae on the Oregon State University Agricultural test station are easily detectable. The same is true of bridges, fences, metal power line poles and metal targets in urban areas. Not as well documented are features such as stream courses and variations in forest and crop sites. The complex diaelectric constant, surface roughness and radar shadow which formulate the radar signal can be useful in interpreting the vegetated areas. For example the riperian vegetation adjacent to the many streams issuing from the Coast Range make good targets. The primary feature detectable is the radar shadowing. When this shadowing is combined with the diagnostic pattern of a meandering stream interpretation is simple. Size of shadows and the length of the pattern give further evidence as to the size and flow rate of the stream. The same approach was used in vegetation identification. The leaf pattern vs the radar band width (X band - 3cm) is the primary determining factor in the roughness imaged on the radar. It was possible to identify some of the vegetation, but the various look directions resulted in variable signals. This is an aspect where more detailed interpretation and evaluation is needed. The thermal infrared imagery (TIR) was especially useful in identifying the location of: changes in soil moisture, harvested crops, burned fields, water bodies, bare soil, and various road types. The TIR was collected pre-dawn to minimize the effects of solar heating.

A combination of sensors appears to be the most useful approach to terrain analysis for a military operation. If only one sensor was possible, the aerial camera panchromatic would be the primary choice. However, if two sensors are available, a radar system plus an aerial camera system would result in the most useful information for general purposes. The radar compliments the panchromatic photography in many areas where metallic features are present. Radar also has the advantage of all-weather capability and an oblique look-direction so that targets need not be flown over directly. However, radar interpretation necessitates experience in vegetation analysis. The thermal infrared scanner imagery provides the most useful information for features such as urban areas, road types, soil moisture and land-water boundaries.

PREFACE

This Addendum to the Multi-Source Image Analysis report #ETL0208 was produced with ammended funds (P00002) to contract DAAK70-78-C-0180. The funds were provided by the U.S. Army Engineer Topographic Laboratories. Many persons were helpful in producing this report including; Michael Mel, Debra Shiroma, Jacques Loraine and Fran Gruenthal of ESCA-Tech Corporation; Colonel Goying, Capt. Hammon, and Sgt. Crosby of the Oregon Army National Guard; Charles Rosenfeld, Ph.D. of the geography department of Oregon State University; and Stuart Wooley of the Oregon State University graduate school. Every effort has been made to make this list complete, but the authors apoligize to any person inadvertantly left out. The authors take full responsiblity for all presentations, interpretations and conclusions presented.

The U.S. Army Engineer Topographic Laboratories contracting officers' representative was Joseph H. Kitrosser. The authors are grateful for his cooperation, guidance and reviews during the preparation of this report.

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1 - INTRODUCTION

Purpose and Scope

The purpose of this report is to compile a set of remote sensor reference imagery through simultaneously collected terrain sensor data. The types of imagery acquired include black-and-white panchromatic photography, radar, thermal infrared, and Landsat digital data and imagery. The reason for collecting this reference imagery is to evaluate and compare feature signals on the three types of sensor data. In addition, ground survey information was collected in order to confirm detail interpretation of the imagery. This was done as near to simultaneous with imagery collection as possible. Three two-person teams made up the ground data collection personnel.

The location of the test area near Corvallis, Oregon, is on the boundary between the Coast Ranges and the Willamette Valley of northwest Oregon. It was chosen as the test area for the collection of this reference image set because of the variety of terrain features present, and the inclusion of a particular physiographic site of interest to the U.S. Army. This site is the Fulda Gap look-alike.

The panchromatic photography has stereoscopic coverage, and the radar coverage has four different look directions - north, south, east, and west. Thermal infrared imagery covers the entire test area. Simultaneity between the various imagery types was of primary importance so that little or no temporal changes are discernible between coverages. Landsat data has been digitally classified on the basis of spectral reflectance classes calibrated with known ground features.

Detailed interpretation of each type of imagery was performed for eight sites within the test area. These sites were selected for their varied features and include examples of the following types of terrain: agricultural lands, forested areas, urban areas and river bottomlands. Emphasis was placed on the analysis and correlation of the three types of imagery and ground truth information.

Description of Test Area

The site chosen for the collection of a reference image set is the area just north of, and including Corvallis, Oregon (Figure 1.1, next page). This roughly 550 square kilometer area includes portions of both the Coast Range and Willamette Valley Physiographic Provinces of Oregon. It offers a wide range of terrain and cultural features for analysis. From the Coast Range foothills to the broad valley of the Willamette River distinct changes in physiography, geology, soils, vegetation, and land use are encountered. The Coast Range foothills consist of volcanic and

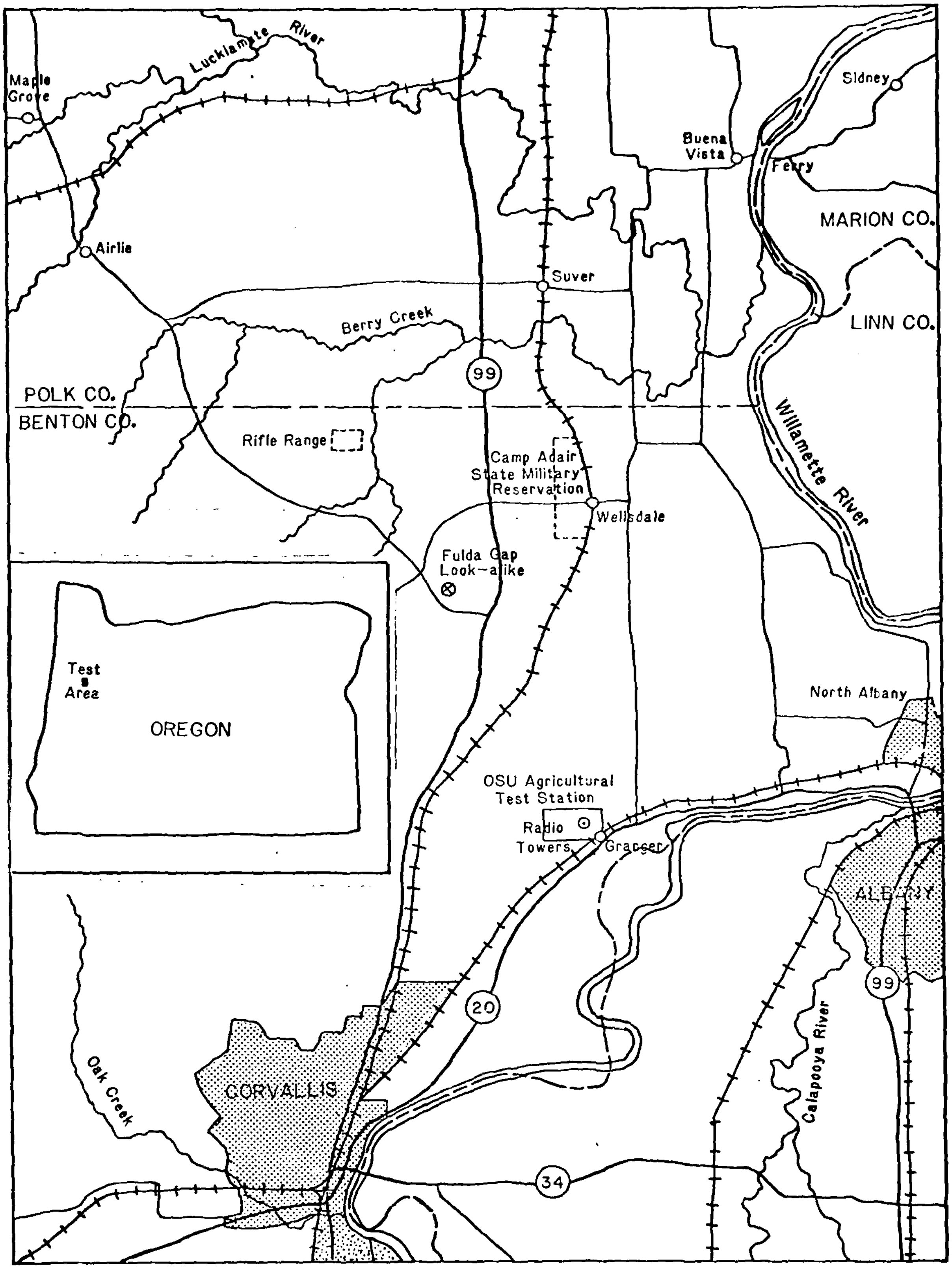

Figure 1.1: General Location Map

marine sedimentary rocks and are heavily forested. The generally flat valley floor is composed of alluvial deposits and is dominantly agricultural. The relatively high precipitation, especially in the foothills, results in a complex drainage pattern within the test area. Most minor streams flow eastward toward the Willamette River which, in turn, flows slowly northward in a highly meandering fashion. The Willamette Valley is considered a mature stream valley.

The test area also contains a wide variety of cultural features. The urban areas of Corvallis and Albany, along with several smaller towns, are interconnected by railroads and numerous road systems. In the center of the test area is Camp Adair, a former U.S. Army base. Adjacent to Camp Adair is the Fulda Gap look-alike location. The real Fulda Gap is a physiographic feature along the border between East and West Germany which could possibly be a primary strategic site in the event of military activity in Europe. Further south, near Granger, Oregon State University operates an agricultural test station where a number of experimental vegetation features are located. Also at this location are two radio station transmitter antennae.

2 - INTERPRETATION

Introduction

The evaluation and analysis of the imagery was based on established capabilities in the interpretation of remote sensor information. Eight different locations within the test area were selected for detailed interpretation and analysis. The locations were chosen for their varied terrain features and include urban areas, agricultural areas, forested areas, and river bottomlands. In each case all three types of imagery have been interpreted, compared, and discussed in detail as to the features detectable and the reasons for their detection, or the inability of a particular sensor to detect that feature. Emphasis was placed on correlation between the three imagery types and with ground truth information.

Note: Underlined figures are found in the back pocket of this report.

Traverse 1

CORVALLIS, OREGON, *TEST SITE*

Introduction

Corvallis, Oregon was selected as an urban test site because of the various cultural features present within a small area. The topography in the area is predominantly flat or slightly undulating. Streams and rivers are widely meandering and the relief immediately adjacent to the stream or river is not extreme. This type of topography is typical of a mature gemorphological stage.

Since the area is relatively flat and water very abundant, it is ideal for farming. Also, since Oregon State University is located within the city of Corvallis the area is locally heavily populated.

Principal features of interest for this area are croplands, bare ground, marshland, different types of houses and commercial buildings, power lines, natural vegetation, and residential areas.

Panchromatic: (Figure 2.1)
The panchromatic image shows detail of the area immediately adjacent to and including the Oregon State University campus (OSU). Specific

targets evaluated are the football stadium (S), parking lots (P), roads (labeled), new construction sites, native and cultivated vegetation, drainage areas and buildings. In the panchromatic image these features can all be observed with the aid of a stereoscope. Many features are large enough to be seen without the aid of the stereoscope but the relative height of buildings is only recognized by stereovision.

Test sites 1-1, 1-2, 1-3, and 1-4 can be identified on this photograph. Fields of cut grain north of site 1-3 appear as light tones on the image due to the light gold color of the crop. Most roads within the area are asphalt and appear dark toned in the image. Trees appear as dark tones because of their dark green colors. Rural areas where houses and barns occur are generally a mixture of light and dark tones with rectangular shapes.

Figure 2.2 is a 35 mm photograph of the downtown Corvallis area. The picture was taken at the corner of 3rd. Street and Jackson Ave. This photograph shows asphalt roads and large commercial buildings within the Corvallis community. The same type of targets are present within the panchromatic image (Figure 2.1).

Figure 2.2: 35 mm photograph
showing downtown Corvallis area

Radar (Figure 2.3)

On the radar image of the Corvallis area many large features are easily identified despite the relatively low resolution. The football stadium at OSU is identified by its shape and position and can be distinguished from other structures in the area. The radar return from the stadium is strongest on the east and west side because the look direction (LD) of the radar antenna is normal to the long axis of the building. The light poles along the periphery of the field act as corner reflectors for the radar signal producing strong returns. Drainage areas are enhanced by the abundance of radar shadows from large trees along their courses. These trees disrupt the predominantly flat farmland and produce stronger radar returns in the near range direction. Because trees border the creeks and rivers, the creeks and rivers themselves can be indirectly identified. The Willamette River is a good example of this feature. The water, however, acts as a specular target and reflects the electromagnetic energy (EM) at an angle equal to the angle of incidence. No energy is returned to the antenna and a dark signature is recorded. The sharp contrast between the trees and the water enhance the course of the river tremendously. Large buildings and especially metal buildings reflect the radar energy back to the antenna very strongly. This produces very strong or bright signatures due to the electrical properties of the metal interacting with electromagnetic energy of the radar pulse. Large buildings produce strong returns because of their geometry and relief with respect to the surrounding terrain. Abrupt changes in elevation cause those objects to act as corner reflectors and produce very strong radar returns.

Vegetated areas such as cropland and native grasses have speckled intermediate signatures due to the random scattering effect of the radar pulse on the vegetation. The EM energy is scattered in various directions due to the random orientation of leaves and twigs.

Another interesting point in the radar image of the Corvallis area is the orientation of the streets relative to the look direction. It can be observed on road maps that the area in the north part of the city is dominated by north-south trending streets. In the central part of the city, directly east and northeast of the campus, the streets are oriented NE-SW. These NE-SW oriented buildings reflect the radar pulse away from the antenna and produce dark signatures on the radar imagery. In other areas, where the streets are oriented N-S, they are perpendicular to the look direction of the radar antenna creating corner reflectors that produce strong returns and a bright signature. The asphalt streets act as specular targets and reflect the EM energy away from the antenna producing dark signatures on the image. Gravel roads produce intermediate signatures due to the higher surface roughness. Rocks and gravels reflect EM energy similar to the way grasses do.

Thermal Infrared (Figure 2.4)

For the thermal infrared image of the Corvallis area target areas are the same as previous examples. Most of the buildings that appear cool are metal structures. Some exhibit a loss of heat from doorways and large windows, especially buildings in the campus area. Asphalt roads, tennis courts and non-metal roofs show warmer or light signatures due to the thermal properties of these substances. It was found in previous studies that asphalt cools very slowly and because it is dark (low albedo) it absorbs much more heat during the day than material like concrete (high albedo). For this reason roads and some buildings are easily identified on thermal infrared images. Radiant temperatures taken of the road and the nearby vegetation at sites 1-3 and 1-4 show a temperature difference of 1 to 3^{o}C. Film densities of these objects are light for roads, darker for vegetation and still darker for bare ground. Large buildings north and east of site 1-4 record very cool temperatures on the TIR image. This is the result of the building being constructed of concrete. This material tends to cool rapidly producing a cool-dark signature on the TIR image.

An interesting feature on the image is Parker Stadium (S) located near the O.S.U. campus. By looking at the stereo images it is noted that the stadium seating areas are inclined so that the east bleachers face SW and the west bleachers face NE. The east bleachers appear warmer than the west. This is the result of the sun's energy striking the SW facing part of the stadium last. The NE facing area was in the shade in the late afternoon and was beginning to cool off long before the SW facing area. Since the cooling rate is the same for both sides, the SW facing area remains warm longer after sunset.

Broad-leafed tree canopies (T) along Oak Creek are identified on the thermal infrared image by warmer signatures adjacent to the cooler grassy areas (g). The warmer signatures expressed by the trees are the result of warm air collected during the daylight hours not being able to escape readily through the trees during evening hours. Several orchards (O) in these areas show individual trees. The tree canopies in these areas do not overlap each other and the cooler radiant energy from the grass area produces a higher contrast which helps to delineate the individual trees.

The new construction site in the northern part of the campus shows some interesting features. In the panchromatic image the construction site shows a hole excavated to lay foundations, piping, etc. Bare ground (P) is present all around the periphery of the site and appears cool in the thermal infrared image. The ability of a material to absorb and transmit energy is called emissivity. Materials with low emissivities absorb and radiate lower amounts of energy than those with higher

emissivities. The emissivity of bare ground is lower than that of concrete and therefore it appears considerably cooler. The concrete, in turn, appears warmer, especially here because these concrete slabs are present within holes where less circulation occurs.

GRANGER, OREGON, AGRICULTURAL TEST SITE

Introduction

Granger, Oregon, was selected as a test site because of the close proximity of several different test features. The KOAC radio towers, rural communities, agricultural plots, and forested areas are some of the test features within very short distances of each other. Low voltage power lines are also present within the test area but are difficult to distinguish on the imagery. Ground truth collection sites 1-11, 1-12, and 1-13 are located within this set of imagery.

Panchromatic (Figure 2.5)

Topography and cultural features present within Granger and the Agricultural test site are easily identified when viewed through the stereoscope. Three-dimensional viewing illustrates the general height relationship of various buildings as well as the topographic relief. Forested areas (T), cropland (C) and fallow ground (P) can be distinguished by differences in film density. Row crops versus grain type crops can be defined by the appearance of linear rows within the fields. The row crops include corn, soybean and sunflowers. Test sites 1-12 and 1-13 are present on this set of photographs. Streams and residential areas (H) are identified by their general shape and tonal characteristics. Ponds and lakes (W) all show high contrast with the surrounding areas.

Figure 2.6 is a 35 mm photograph taken at the Oregon State Agricultural Test Station. The photograph shows the small agricultural test fields with fallow ground, soybean and sunflowers present. In the background are the radio towers that are located within the agricultural test station. This photograph was taken at test site 1-12.

Figure 2.6: 35 mm photograph
of the Oregon State Agricultural Test Station

Radar (Figure 2.7)

The radar imagery of the Granger area has a low resolution. However, large features such as Logsden Ridge, Adair Village and other areas are easily defined. The KOAC radio tower (R) and several metal structures have high radar return due to the electrical properties of the metal and the interaction with the electromagnetic energy from the radar. The radio towers act as corner reflectors which also produce strong radar returns. Lakes and other large water bodies have dark signatures due to the radar signal being reflected away at an angle equal to the angle of incidence. These are known as specular targets.

Densely forested areas and large river areas are highlighted by the abrupt change in surface configuration. For this X-Band SLAR system, the ground resolution cell limits the use of the system for any detailed crop evaluation. Since radar return is based on the surface configuration of particular objects, all areas that are densely vegetated tend to produce intermediate signatures regardless of the vegetation type. However, fallow ground and cropland can be distinguished by dark signatures representing fallow ground and speckled-intermediate areas representing vegetated cropland.

Railroads (RR) appear as continuous, bright linear features that cross fields and generally interesect major communities. They are best enhanced when the track is normal or at an oblique angle to the look direction. When the track is parallel to the look direction (range direction) identification is difficult.

Thermal Infrared (Figure 2.8)

The primary reason for selecting this area as a test site was for crop and soil moisture evaluation. This area has several ponds and larger open bodies of water as well as several areas with varying soil moisture. Other information gathered within this area includes the delineation of crop types and their state of growth. In the thermal infrared images of this area, drainage patterns are enhanced by cooler signatures (darker) in small dry gullies and warmer signatures (lighter) where water is present. Semi-linear features represent both mature as well as younger drainages. These are identifiable even where the area has been cultivated and planted with crops.

In bare soil or fallow ground the signature on the TIR is relatively cooler than in areas which are densely vegetated. The Oregon State University Agricultural Test Station is a good area to monitor this feature. Several small plots are within a very short distance of each other and are at varying growth stages. At test site 1-13 radiant temperatures of bare soils are roughly 2°C cooler than the surrounding vegetation. At test site 1-12, five days prior to airborne TIR collection, water was present on the vegetation crown making the vegetation cooler than the soil.

Trees and other plants with large leaf structures tend to collect warm air on the underside of the leaf canopy and prevent rapid heat loss. Therefore, the signatures from trees and other large leafed plants are warm on the nighttime TIR. Bare soil has no insulation, and since rocks and soils are poor conductors of heat, they have relatively cool signatures on nighttime TIR.

In areas surrounding the Willamette River, several meanders have been cut off to form oxbow lakes. These free-standing water bodies appear warm on the nighttime TIR because they remain at more or less constant temperature. During the day the water is generally cooler than the ambient air temperature and surrounding objects, whereas during the night the water is warmer than ambient air temperature and the surrounding terrain. Again, since rocks and soils are poor conductors of heat, the dry, bare ground cools along with the cooling air and therefore appears dark on the nighttime TIR image. In deep water bodies convection currents do not allow the water to cool very rapidly and as a

result, over short periods of time they have fairly constant temperatures. In areas of varying soil moisture content, film density increases (i.e., tone appears darker) with increasing moisture content. This is due to the effects of evaporative cooling.

NORTH ALBANY TEST SITE

Introduction

The North Albany area was selected as a test site because of the urban, rural, and small industrial features that are located within this area. Lumber mills and their ponds provide test site localities for the identification of industrial activity as well as other businesses associated with the mills. Railroad yards, major highways, railroad and automobile bridges are all present at this test site. Trees border the Willamette River but dense forests are absent. Test sites 1-17 and 1-18 are located within this set of imagery.

Panchromatic (Figure 2.9)

In the panchromatic image urban areas (H) contain numerous residential sites and scattered commercial buildings. Railroad tracks (RR) and roads can be differentiated with the aid of a stereoscope. Railroad tracks appear irregular in shape whereas roads are fairly uniform. Industrial (I) and commercial sites contain large buildings and are generally located at major road intersections or around the peripheries of residential areas. Golf courses have wide linear grass paths and trees line the driving range.

Agricultural plots are both rectangular (C) and circular (C1) in shape. The shape is strictly dependent on the irrigation technique used. This test site is somewhat different from other sites within the test area. Other areas are dominated by rectangularly shaped fields. These agricultural sites or croplands appear as various tones within the image due to the various crops that are being grown. Wheat fields appear light toned due to the light gold color of the crop. Barley, clover, and corn appear darker toned due to their dark green color. On the circularly irrigated fields irrigation pipes can be identified as light toned dots within the field. Tree and grass areas adjacent to the Willamette River appear as dark toned areas. The trees appear darker than the grasses due to the reflectance from the leaves and the plant size differential.

The Willamette River (W) appears as a dark toned linear feature that traverses the image. Where the sun is strongly reflected by the surface of the water, the tone is considerably lighter. Mill ponds (W1),

reservoirs (W) and oxbow lakes (W) appear dark toned due to the dark tone of the water. Using the stereoscope, depressions where the water bodies occur are easily identified. Highlands around the river and creek gullies are highlighted due to the vertical exaggeration inherent in the imagery.

Figure 2.10 is a 35 mm photograph taken at test site 1-7. This photograph shows the Willamette River and the surrounding riparian vegetation. This vegetation consists of grasses, scrubs and taller conifer and oak trees.

Figure 2.10: 35 mm photograph of the Willamette River.

Radar (Figure 2.11)

The radar imagery of the North Albany test site has some very distinctive features present. The three bridges that cross the Willamette River are well defined. The contrast between the low return of the water and the high return from the bridge make identification easy. Residential areas appear as bright areas while the radar return from the large commercial buildings is so bright that no additional detail of the area is possible. Agricultural areas appear as speckled intermediate tones where crops are present, dark tones where the ground is fallow. The intermediate speckled tone of cropland is the result of the radar signal being scattered in various directions by the random orientation of the leaves and twigs. Fallow ground acts as a specular target in the X-Band wavelength as all of the radar energy is reflected

away from the antenna and a dark signature results.

Water too, acts as a specular target producing dark signatures wherever large bodies of it are present. This is observed in the image by the dark linear feature representing the Willamette River. Lakes and millponds east of Albany also appear dark but the boundary or shoreline is not well defined due to the abundance of trees. Trees produce intermediate speckled signatures the same as vegetated areas. However where they are adjacent to croplands they are enhanced due to the abrupt change in relief from the tree canopy to the lower-lying crops.

Railroads are well defined when they pass through agricultural areas. However, when they pass through residential and commercial or industrial areas the strong return from the buildings hide the return from the railroad tracks. Roads in agricultural or rural areas are dark (specular) except for roads that are lined by large trees. Then they become bright due to the strong return created by the interaction of the radar signal with the road and trees.

Thermal Infrared (Figures 2.12 and 2.13)

In the thermal infrared images of this area the same test sites are identified. Urban areas are identified by the small rectangularly shaped polygons formed by the numerous asphalt streets that run perpendicular to each other. Individual houses appear as very small polygons with various film densities. The lighter toned polygons are warm buildings with various film densities. The lighter toned polygons are warm buildings whereas the darker toned polygons are cool buildings. This temperature difference can be attributed to several things. The most prominent difference in tone can be related to the various construction materials used. Metal-roofed or aluminum-sided buildings are considerably cooler than wood frame stucco houses with shingled roofs. Mobile homes (Hm) are the most striking examples of this feature. The cooler signature from metal roofs is due to the thermal properties of metal. They have lower emissivities than stucco or other non-metallic materials. Large industrial areas (I) and commercial areas (C) can be identified by their larger size. In downtown Albany commercial areas are further characterized by large light toned, asphalt parking areas adjacent to the darker toned and cooler buildings.

The golf courses appear as both light and dark tones, corresponding to the tree and grass areas respectively. Warm air from day-time solar heating tends to collect under tree canopies giving warmer signatures on the thermal infrared image. The darker tones represent the cooler grass areas. Other trees and grass areas (T/G) also appear this way. Agricultural areas have various tones or film densities which can be related to the various crop types, stages of growth and soil moisture.

The lighter toned fields are warm and correspond to grain crops where warm air is collected under the large stalks and held there. The smaller sized, larger leafed crops are cooler possibly due to less warm air being held near the ground. These areas are all considerably warmer than the very cool objects such as mobile homes (Hm). Orchards (O) appear as light and dark spots, again corresponding to the warm trees and cooler grasses. Soil moisture content can also cause agricultural areas to respond differently. Moist ground appears much cooler than dry ground due to evaporative cooling.

Water bodies such as the Willamette River (W), oxbow lakes (W), and mill ponds (W1) are considerably warmer than surrounding objects. Solid materials such as rocks and buildings cool more rapidly and have a lower radiant temperature than the adjacent water. The Willamette River appears cooler (darker toned) than the oxbow lakes and mill ponds because the water is continuously replaced by fresh water from source streams. In the mill ponds and oxbow lakes the water is allowed to remain in one area and therefore over a long period of time tends to warm up. This solar heating requires many days of warm temperatures in order to increase the temperature of the water. Restricted water therefore tends to be warmer than free flowing rivers.

Railroads and residential streets can be differentiated by their different tones. Railroad tracks appear cooler than the surrounding asphalt streets. This is the result of the construction materials used. The railroad tracks are constructed of gravel and bare earth. These rock materials are poor conductors of heat and as a result have low emissivities and low thermal conductivities. Asphalt however is a good conductor of heat and therefore appears considerably warmer or lighter toned in the nighttime thermal infrared imagery.

Traverse 2

FULDA GAP LOOK-ALIKE TEST SITE

Introduction

The Fulda Gap look-alike area was selected as a test site because of the numerous terrain features which resemble the Fulda Gap in Germany. A hilly terrain with a rifle range, open pit quarry, and agricultural sites, plus a variety of tree species are all located within very close proximity to one another. Roads consist of asphalt, gravel and oiled

surfaces which provide a variety of information on how specific road building materials appear on the different sensor types. Vegetation consists predominantly of large oak trees and natural grasses where farming has not altered the natural environment. Relief in the area is moderately rugged with the elevation ranging from roughly 75 meters to 250 meters. These abrupt changes in elevation are easily identified on the radar image and will be discussed completely in that section. The principal rock types in this area are Tertiary volcanics and Quaternary alluvium. As a result, the rock or soil material within any specific locality is fairly homogenous.

Panchromatic: (Figure 2.14)

In the panchromatic image densely forested areas are dark and the farmland is light. Distinct boundaries between forests and farmland are easily delineated. Crop and growth stage identification is difficult in these images due to the similar appearance of the various crop types. Roads are easily identified but their construction material is difficult to determine. One can delineate heavy duty versus light duty roads by their size, relative straightness and construction material. Drainage areas are highlighted by the presence of trees and their arrangement in a highly meandering pattern. Grassland and lightly forested areas appear as a medium toned with a few trees scattered about. Agricultural fields are observed to contain wide furrows which help to delineate them from grasslands. Under stereovision the scene can be viewed in apparent three-dimension. This enables a delineation of specific topographic features. Height of trees and large buildings can be estimated when the flight attitude is known. The rifle range has several characteristic features that can be observed with the use of the stereoscope. The earth backing can be observed on the east side of the range as a small linear hill that runs parallel to the western boundary of the range. The roads leading up to the firing range are easily identified and the firing range control tower can be identified as the only building structure on the premises. The open pit quarry on the east side of the little gap is identified by the fact that much earth material has been removed from this side of Coffin Butte. Numerous roads also criss-cross the area and lead in no specific direction. When viewed under the stereoscope, earth moving equipment can be observed scattered about the area. The roads switch back and forth up and down Coffin Butte and a large workyard is present in the middle of the site.

Figures 2.15 and 2.16 are 35 mm photographs showing two examples of dirt or gravel roads and the surrounding vegetation at ground data sites 2-14 and 2-15 in the Soap Creek canyon near the Coast Range foothills.

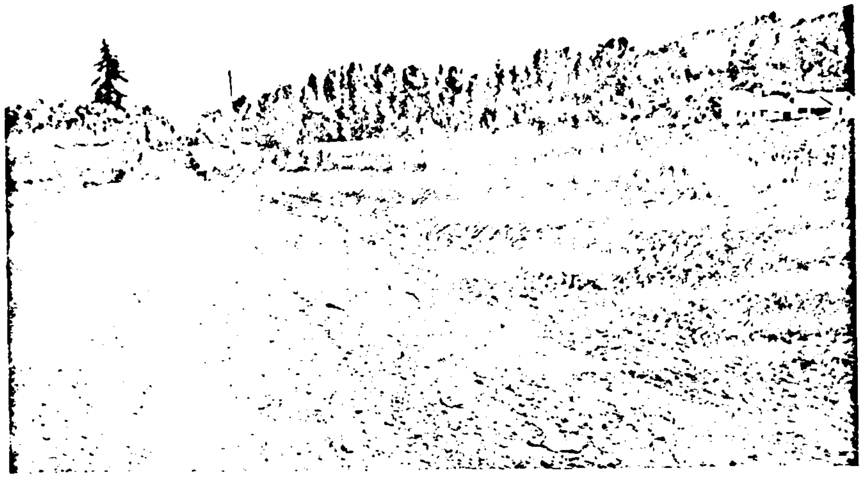

Figure 2.15: Gravel road and surrounding vegetation of natural grasses and trees (Site 2-14).

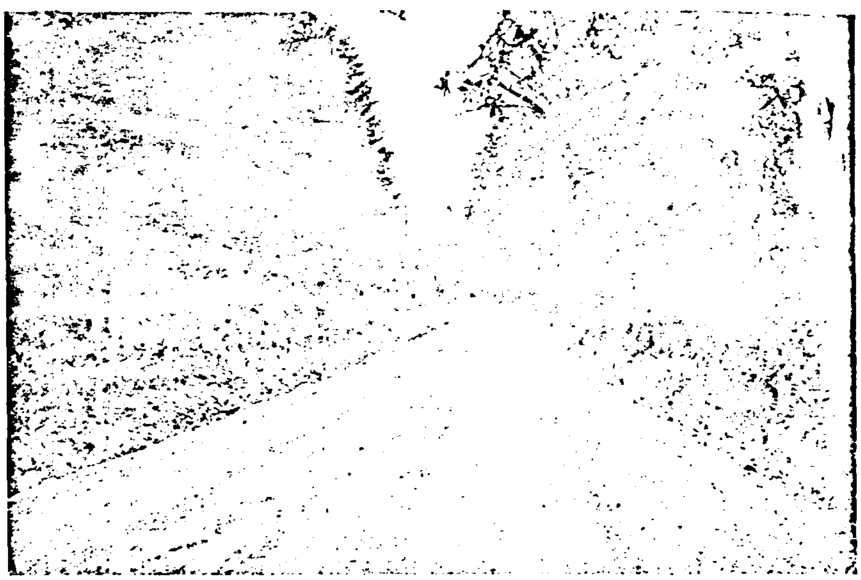

Figure 2.16: Gravel road through mixed forest of the Soap Creek canyon (site 2-15).

Radar (Figure 2.17)

In the radar imagery of the Camp Adair-Fulda Gap look-a-like area several features are easily identifiable. Coffin Butte, Adair Village, Logsden Ridge, and tree-lined creeks are among the most prominent features. Radar shadow areas play an important role in the determination of flight patterns. As noted in this image, shadows are present on the southeast side of the large mountains, this is the side opposite to the survey aircraft. In mountainous areas radar imagery should be flown over an area in at least two directions to insure shadowing does not cause a specific feature to go unobserved. When two flight directions are utilized, 90° apart, the shadowed area of one flight could be observed on the other flight.

Adair Village is identified by the strong radar return from the buildings. The buildings act as corner reflectors which produce strong returns to the receiving antenna. Metal buildings also produce strong returns. An example of this can be seen at the rifle range. Strong returns from metal objects are due to their electrical properties. Crop dfferentiation at this wavelength is somewhat difficult since the surface roughness for X-Band radar is similar for both row crops and grains. Both produce a speckled return of intermediate intensity. Trees along creeks are well defined because their abrupt change in relief produces a strong signature on the side closest to the antenna. Where forested areas start on the hills and mountain slopes little delineation can be made because the return is mostly generated from the mountain rather than the trees. Only where abrupt change in relief occur (i.e., trees next to crops or fallow ground), can delineation be made.

Numerous farmhouses and barns can be observed in the radar image. These are identified by very bright signatures scattered throughout the farmland. Small ponds and irrigated lands are difficult to identify on this image due to excessive shadowing. Water bodies should appear as dark signatures on the radar image because water acts as a specular target, that is, the electromagnetic energy from the radar beam is reflected away from the radar at an angle equal to the angle of incidence but opposite in direction. Therefore, the electromagnetic energy is all reflected away from the antenna and thus no radar return is produced. The resolution of this imagery prohibits the ability to detect a signal from most of the small farm ponds.

Thermal Infrared (Figure 2.18)

In this thermal infrared image, numerous features are identifiable. Trees, grass areas, roads, water bodies, buildings, streams, crops, and bare ground can be identified in TIR image with only slight aid from maps and aerial photographs. In the thermal infrared image of the Fulda Gap look-alike area, roads are constructed of three basic types of material: gravel, asphalt and oiled surface. Since they have different

thermal properties, the response from these different surfaces are also different. Asphalt paved roads appear the warmest in the nighttime TIR imagery. This is due to the fact that asphalt absorbs more heat than rock and that its ability to radiate heat is greater than than of the rock. It is found in Sabins (1978), that granite (a common rock material for use in gravel roads) has an emissivity of about 0.815. For asphalt the emissivity is 0.959. Emissivity is basically the ability of a material to both radiate and absorb energy. Materials with low emissivities radiate smaller proportions of kinetic and incident energy than substances with high emissivities. From ground truth data collected near the Fulda Gap look-alike area, it was found that gravel roads were generally 1 to 2^{o}C cooler than the asphalt and oiled roads. In the thermal infrared imagery of this area the asphalt roads have a much lighter film desnity than roads made of gravel. Spot density measurements of these areas were taken to show the density difference due to difference in radiant temperature. (Table 2.1). These values, however, will also vary with ambient air temperature, length of time incident energy is absorbed and the time at which radiant temperature measurements are taken. Therefore, these values only illustrate the relative differences for these materials.

Trees or heavily forested areas in this area are primarily conifers and large leaf oak trees. In areas consisting primarily of oak, the broad leaf trees tend to collect warm air during daylight hours and trap this air under the tree canopy. This in turn causes the radiant energy to be much warmer than areas where predominantly grasses occur. Grasses, being small-leafed and low-lying, cannot trap warm air and as a result tend to change temperature very readily. This allows the radiant temperature from grass areas to be close to or even cooler than, ambient air temperature. In areas where the tree canopy is limited to a single tree, that individual tree can be identified due to the temperature difference of the ground or grass and the warm air under the tree. This sharp contrast in temperature enhances the two objects and they appear on the film image as light and dark spots on the film--light representing warm trees, dark representing cool grass areas.

An interesting feature is the warm signature in the lower right-hand corner of the image. On the aerial photograph this area consists of trees and farmland. However, in the TIR image this area does not appear the same as other areas of trees and farmland. This warmer signature is probably due to fog or low-lying clouds. On nighttime imagery clouds appear warmer than the surrounding area. Heavy overcast generally reduces thermal contrast between terrain objects because of reradiation of energy between the terrain and cloud layer (Sabins, 1978).

Soil moisture content for this area ranges from about 5.2% to 6.9% (taken from sites 2-19 to 2-22). Using only the unaided eye, detection of such minute differences in moisture content for these soils is

extremely difficult. Film density differences can be attributed to many other factors in this area. Therefore, it would be erroneous to conclude that soil moisture content of this degree could contribute to radiant temperature differences greater than $1/2^{\circ}C$. Test experiments performed under controlled conditions reveal that soil moisture contributes to cooler measurements by thermal infrared radiometers. A temperature difference of $0.5^{\circ}C$ occurs between 0% and 5% soil moisture. No temeprature change between 5 and 11%. $0.5^{\circ}C$ between 11% and 16%, $0.5^{\circ}C$ between 16 and 20%, and no change between 20 and 29%. These temperatures are taken from the 0400 hour reading. A complete description of the experiment is discussed later in the text. It is observed that ponds or large bodies of water are easily identified in the nighttime thermal IR image due to their warm signature. Because large bodies of water take longer to change temperature, diurnal variations are minimal. In fact, for very short periods of time the temperature is nearly constant. On nighttime or predawn flights large water bodies appear warmer than the surrounding objects.

In the thermal infrared image cropland appears slightly warmer than fallow ground. This occurs because vegetation tends to insulate the ground, trapping warm air and prohibiting rapid heat loss. Fallow ground appears cool because of the lack of insulation and because rock material (soil) is a poor conductor of heat. Evaporative cooling is also a possible contributing factor since soil moisture content ranges from about 2% to 25%. Cultivated farmlands appear warm, somewhat the same as forested areas. Cropland, however, can be distinguished from forested areas by geometric shape. Farmlands appear generally rectangular whereas forested areas are more irregular.

CAMP ADAIR TEST SITE

Introduction

The Camp Adair Test Site was selected because of the abundance of natural vegetation present within the area. Asphalt and gravel roads also traverse the area quite extensively so that evaluation of several types of road construction materials can be made on one image. Abandoned housing tracts as well as large industrial buildings are also present within the area. Agircultural areas are present east of Camp Adair and are included in the interpretation. Ground truth test sites within this area include 2-6, 2-7, 2-8, 2-9.

Panchromatic: (Figure 2.19)

The panchromatic image of the Camp Adair area is representative of 3 distinct types of land use. The eastern-most portion of the image is dominantly agriculture with irregularly-shaped polygons of grain crops, orchards and row crops. The west-central part of the image is dominated by the Wilson Game Management area and consists almost entirely of grass and trees (natural vegetation). The western-most part of the photo is hilly and consists of mine quarries and densely forested areas.

Using the stereoscope, changes in relief are easily recognized and height relationships between buildings can be assessed. Coffin Butte can be identified and an open pit quarry can be observed on the east facing flank of the hill. Cut-off meanders in the agricultural areas also show changes in relief from the surrounding areas.

Croplands can be identified by their rectangular shape. Light-toned areas are typical of cut grain fields, intermediate-tone fields of growing crops and dark-toned fields are typical of corn, clover, or plowed or burned fields. By using the stereoscope one can also define row crops versus grain crops. Residential areas are identified by light and dark-toned extremely small polygons. They are generally located adjacent to roads and are usually surrounded or partially surrounded by trees. Densely forested areas are also dark-toned and when viewed through the stereoscope, have considerable relief associated with them. They also tend to form irregularly shaped polygons.

Figure 2.20 is a 35 mm photograph of typical cropland as seen at ground data collection site 2-6. This field is composed of cut hay and stubble.

Figure 2.20: Typical field of cut hay and stubble to the east of Camp Adair.

Radar (Figure 2.21)

The radar image of Camp Adair is considerably smaller in scale and it is difficult to identify the small targets. The large cell resolution for this X-Band image prevents much detailed analysis. Large buildings (B) are bright-toned due to the strong radar return. This strong return is caused by the radar signal being reflected back almost totally by the building. Corners and edges of the building act as corner reflectors and return most of the energy sent from the antenna back to the antenna. In the remainder of the Wilson Game Management area, intermediate signatures are recorded due to the abundance of natural vegetation that occurs there. In the agricultural area to the west, intermediate and dark-toned polygons are recorded indicating cropland and fallow ground. Irregularly-shaped dark areas are large oxbow lakes that are acting as specular targets.

Shadows or dark areas to the east of Coffin Butte and other hills indicate the radar was acquired in a N-S flight direction with the look direction generally to the east.

Railroad tracks (RR) appear as bright linear features on the image. This is the result of the interaction between the radar signal and the metal tracks. Roads are hard to define in this image because they appear dark (specular target) and with the alternating cropland and fallow ground, dark linear features are hard to separate out. In more populated areas where consistently bright signatures are present from the numerous buildings, roads are identified easier by their dark signature. The contrast between the two targets are great enough to enhance one another when both objects are large enough to be detected by the radar system.

Thermal Infrared (Figure 2.22 and 2.23)

Side lap between the two images does not exist, therefore coverage of this area is somewhat incomplete. Test sites 2-3, 2-6, 2-7, and 2-8 are located on the imagery and field data taken a few days prior to imagery collection define several specific features. The average temperature difference between asphalt roads and cut grain fields is about 2^{o}C. Dense oak and Douglas fir forests adjacent to site 2-8 have warmer signatures also. Grass (g) areas between Pacific Highway West and Coffin Butte appear cool. The rock quarry itself is warmer. This is attributed to thermal properties of the basalt exposures within the quarry. Basalt has an emissivity of 0.934 (Sabins, 1970). This closely resembles asphalt which has an emissivity of 0.959. Spot density measurements between these two areas reveals a film density difference of only .03 density units. For this reason then the interpretation of a basalt quarry and asphalt roads are based primarily on their geometric shape. Roads are linear in shape and stretch continuously across the

imagery. The basalt quarry is irregular in shape and discontinuous. This basalt quarry produced crushed basalt for use in road construction for Camp Adair during World War II (Baldwin, 1976). Gravel roads appear somewhat cooler than asphalt roads. Density differences between asphalt (.88 density units) and gravel (.92 density units) is only .04 density units. This difference is enough, however, to be detected by the unaided eye. The asphalt roads appear slightly lighter toned than the gravel roads.

At test site 2-6 it appears that new or newly regrown crops have a cooler signature than cut grain fields. The warmer signature of the cut grain fields is due to the insulating ability of fallen leaves and stalks. Warm air collected during daylight hours is held within the closely laid cut crop better than fields where only the stubble of low standing stalks are present. Therefore, light-toned warmer signatures appear on newly cut fields and cool signatures appear on stubble areas or low standing crops. In stubble area, bare ground is more abundant and therefore is the primary object being detected.

At test site 2-5 an irregularly shaped forested area is present on the west side of the road. These trees produce an intermediate tone possibly indicating mostly conifers present in the area. The farmland directly south of this patch of trees is stubble and is represented by a cool signature. The field north of the road is bare ground and only a slight difference in film density can be observed between this bare ground and the stubble field to the west. This probably is the result of the bare ground having a greater influence on the temperature than does the stubble.

Large buildings (B) are also present within the Camp Adair region. The buildings themselves appear as dark-cool signatures, but the parking areas and areas immediately adjacent to the building are considerably warmer. This is probably the result of heat being lost through windows and open doors. The asphalt is warm in comparison to the building because of its higher emissivity. The asphalt roads (Ra) running north and south adjacent to these buildings image as light-toned linear features. Gravel roads (Rg) appear cooler due to lower emissivity of the gravel. Close inspection reveals a non-homogeneous tone on these gravel roads. This is due to variations in construction material. Where basalt is concentrated as the main rock type, the signature is warmer. Areas where gravels, sands and hard soil are the principal pavement material, they appear cooler. On the asphalt roads the tone is fairly consistent due to a consistent pavement material.

WILLAMETTE RIVER TEST SITE

Introduction

The Willamette River test site was selected because of the variety of crops that are grown in the area. Corn, clover, and wheat are the most common. Urban areas are also present but are limited to very small areas. Trees line roads and major drainage areas. The Willamette River traverses the area to the northeast. Several fields were irrigated a few days prior to image collection. Soil samples were taken at these various sites to determine the moisture content.

Panchromatic (Figure 2.24)

In the panchromatic image, typical light and dark-toned polygons of agricultural fields dominate the scene. Asphalt roads appear as dark linear features transecting the fields in various directions. Old meanders have caused shallow ravines to be created. Trees are present along the river and along the meander scars. The few residential areas appear as small, isolated polygons that have been located at major road crossings. Single resident farmhouses are located sporadically along roads and are generally near small clusters of trees.

When viewed through the stereoscope, the topography appears as gently rolling hills transected by a major river (W). Fallow ground, clover and corn fields appear as dark tones on the imagery and are difficult to differentiate with normal black and white photography.

It is suggested by Rao, Brach, and Mack (1978) that the use of certain specific bands within the spectra can be used to delineate between cereal crops and other vegetation. The spectral range suggested by Roa and others is from 350 to 1850 millimicrons with specific crops analysed by a specific narrow band within this range. The specific band is selected for the individual crop by determining at what wavelength the maximum spectral response is located. By then using a multispectral camera with the selected narrow band widths, crop discrimination can be achieved.

A 35 mm photograph of site 2-3 (Figure 2.25) shows a typical agricultural field found in this area. In this case the crop is clover in the process of being watered. The rows of clover are oriented north and south.

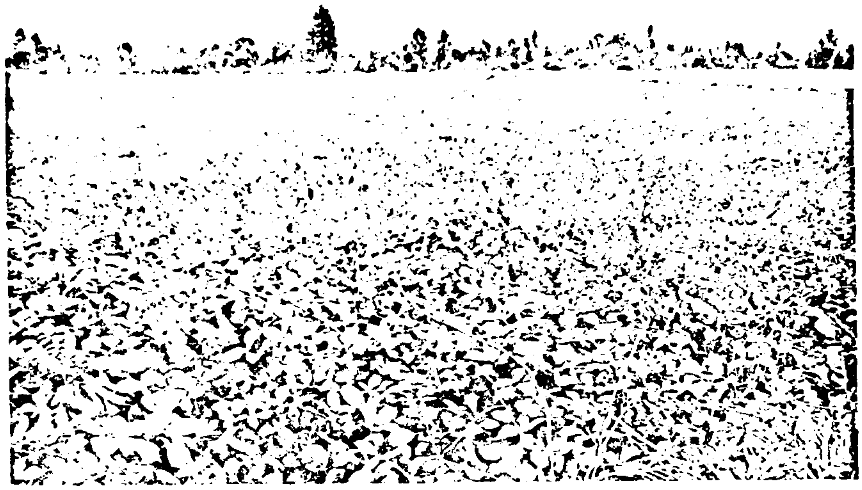

Figure 2.25: Typical agricultural field of clover with rows oriented north-south.

Radar (Figure 2.21)

The radar image that combines both the Camp Adair and Willamette River Test Sites is predominantly agricultural. Crop delineation is difficult at this wavelength and ground resolution. Some detail can be made where fallow ground or cut fields exist adjacent to mature crops. Fallow ground (P) appears dark due to the bare ground reflecting the radar signal away from the antenna (specular targets). Croplands (C) appear as intermediate-speckled signatures due to the random scattering of the radar signal by the randomly oriented leaves and twigs.

One area of particular interest is the Willamette River. The Willamette River appears as a dark narrow linear feature in the north-east part of the image. Again this is the result of the water acting as a specular target reflecting the radar energy away from the antenna. The river is further enhanced by the trees that border its course. This abrupt change in relief causes a bright signature on the side closest to the radar antenna and a thin dark shadow on the far side.

Metal roof buildings (B) appear as bright dots throughout the image. These bright dots are the result of the interaction between the metal on the buildings and the electromagnetic energy from the radar pulse. Metal has an extremely high dielectric constant and as a result produces very strong radar returns.

Railroad tracks that are at an oblique angle to the look direction appear as thin linear bright features that transect the farmland. Railroad tracks that are parallel to the look direction are poorly defined. Both examples exist in the Camp Adair area. Railroad tracks approach from the southwest and then turn north to enter the Camp Adair Military Reservation. That portion of the track that runs NE-SW has brighter signatures than that oriented N-S. The look direction of this image is to the south.

Thermal Infrared (Figure 2.26, 2.27, and 2.28)

On the three thermal infrared images of this area, test sites 2-2, 2-3, 2-4, 2-5 and 2-6 are present. Average temperature differences between asphalt roads and adjacent vegetated fields was 2 to 3°C. This wide variation in radiant temperature causes a sharp contrast between light and dark signatures on the thermal infrared image. A film density difference of about 0.14 density units was identified between crops and asphalt roads using a spot densitometer. This variation in film density is easily recognized by the unaided eye. It is quite apparent in image 141a east of test site 3-2, that the asphalt road has a higher radiant temperature than the warm air trapped under the tree canopy. The road can be traced through the forested area which consists of oak, Douglas fir and spruce. Since asphalt has a low albedo and high emissivity, asphalt absorbs much more radiant energy than the leaf canopy can trap. Therefore, asphalt roads appear much warmer than the trees. Single family residences are generally adjacent to lighter-toned asphalt and gravel roads. Their cool signature is the result of well-insulated buildings that are cooler than the surrounding ground. When lighter-toned structures appear, insulation and building materials are allowing indoor heat to escape. This contrast helps to delineate houses from other objects. Large metal barns and storage bins are constructed mostly of aluminum sheeting. These buildings appear considerably cooler. This is the result of low emissivities from the shiny aluminum surfaces. This low emissivity value indicates the aluminum absorbs less heat and reflects the coldness of space therefore appearing much cooler in the nighttime thermal infrared image.

In the agricultural fields crop types are difficult to differentiate. Plowed or fallow ground versus cropland can be distinguished by the light tones or low film density representing cropland while dark-toned, higher density areas represent fallow ground or predominantly bare soil. Where crops have been cut and are laid in parallel rows, the signature

on the thermal infrared image shows warm areas where the grain has been laid. Where only stubble exists, the signature is cooler or darker. Spot density measurements, Table 2.1, were taken for corn and clover fields adjacent to ground truth site 2-3. On fallow ground the signature is much cooler due to evaporative cooling from the freshly plowed ground. Corn and clover fields appear slightly cooler than the fields which contain wheat or oats. This is the result of large sized stalks capturing and holding more warm air within the stalks than the small leafed low lying fields of young clover. In the area between site 2-4 and 2-5, grain crops have a film density of about 0.94 while young clover or corn have film densities of about 0.84. Thus film density difference of 0.10 exists.

Cut-off meanders, formed as a result of the change in river course, contain soils which are coarse-grained. These coarse-grained gravelly sandy loams tend to collect and maintain cooler temperatures and therefore appear darker on nighttime TIR than finer-grained agricultural soils. In the thermal infrared image of this area, these cut-off meanders are unusually cool compared to the remainder of the area. This is the result of the soil type present in these areas. The cut-off meanders contain predominantly gravelly sandy loams. The adjacent agricultural areas are composed of finer clay loams. From Sabins (1978), sandy soils have thermal capacities of 0.24 $cal.gm^{-1}\,{}^{\circ}C^{-1}$ and clayey soils have thermal capacities of 0.35 $cal.gm^{-1}\,{}^{\circ}C^{-1}$. Thermal capacity is basically the ability of a substance to store heat. The higher the thermal capacity the longer the material takes to cool off after incident energy is removed. This tells us that sandy soils with their lower thermal capacity cool off considerably faster while those soils with higher clay content stay warm longer. Since the TIR was collected at post-sunset the soils containing the coarser gravel sandy loams are cooler than the finer clay loams.

The cut-off meanders tend to be semi-circular in shape and in studying the aerial photographs, tend to contain predominantly natural vegetation (i.e., grasses, shrubs and few trees). The grasses and shrubs that are present within these meander belts show typical cool signatures as a result of evaporative cooling from the greater soil moisture.

The Willamette River can be identified in this image by the continuous warm signature that cuts across the image. The warm signature is the result of water appearing warmer than the surrounding features in the nighttime thermal infrared images. Large water bodies change temperature over very long periods of time. As a result, when analyzed over short periods of time the diurnal temperature remains fairly constant. This is the result of convective currents within the water body continually circulating cool and warm fractions of the water column which in turn maintains a fairly constant surface temperature. Daylight hours however tend to cause thermal energy to be absorbed by rocks,

roads, buildings, and other solid substances. During evening hours (after sunset), radiation from these objects is not replenished causing surface temperatures to be generally lower (cooler signature) than the adjacent water bodies. On ponds southeast of site 2-5 film density measurements of the water is about 0.70 density units. The film density of adjacent cropland averages about 0.88. A difference of about 0.18 density units.

Traverse 3

WILLAMETTE RIVER AT BUENA VISTA TEST SITE

Introduction

A test site along the Willamette River at Buena Vista offers a variety of terrain and cultural features for analysis. Topographically the area is relatively flat since it is within the bottom lands of the Willamette River. As a result, the dominant cultural feature is agriculture. Various types of agricultural crops are present as well as some natural vegetation. Other feature worthy of analysis in this area include a number of farm buildings and houses, asphalt and dirt roads, the river, and a metallic ferry on the river.

Panchromatic (Figure 2.29)

The panchromatic image clearly shows the patchwork appearance of this agricultural area. Individual fields can be distinguished by tonal variations on the image, by dirt roads around their boundaries, and by lines made by plowing equipment. Most fields (C) have a light tone due to the dry vegetation found there. A few fields contain mature corn stalks (Cc) and some fields have been burned to the ground (Cb). Several areas of natural vegetation are seen on the image as dark mottled areas consisting of broadleaf and needle leaf trees (T). These are especially numerous along the Willamette River.

In and around Buena Vista numerous fruit orchards (O) are indicated by the pattern of trees in straight rows uniformly spaced. The town itself is made up of a number of individual houses (H) visible on the image. At the eastern edge of town, at the Willamette River, is a rectangular shaped metallic ferry (F) clearly distinguishable on the image. The river itself has a dark tone, but along its bank are isolated stream deposits (St) on the inside portions of meanders. These areas give a light tone on the image. A small distance south of the ferry, in the middle of the river, is a small motor boat heading downstream.

In the southwest portion of the panchromatic image several meanders of the Luckiamute River are present. Trees are found on both sides of the

river along most of its length. The large bright spot on the image along the river represents the reflection of the sun on the river's surface.

Although this area is relatively flat, some topographic expression can be seen in the northwest corner with the aid of a stereoscope. But in general the topography is such that agriculture is the dominant feature. The extensive agriculture also suggests the presence of well-developed soils. This and the fact that the valley is relatively mature explains why no geologic outcrops are found here except very recent stream deposits along the Willamette River.

Five ground data collection sites are present on the image (3-12 thru 3-16) and are indicated on the overlay. 35mm black and white photographs of sites 3-15 and 3-16 are included here. The 35 mm photograph of site 3-15 at the Willamette River near Buena Vista shows the ferry that crosses the river just south of Wells Island. This feature is also visible on the panchromatic image as indicated. The 35 mm photo was taken on the west bank of the river looking east. Both broadleaf and needleleaf trees are visible along the east bank.

The 35 mm photo of site 3-16 also was taken looking east. Mature corn stalks are present on both sides of the road and can be seen in the photo. The two buildings in the photo are those seen on the panchromatic image due east of site 3-16.

An interesting feature is present in the field of corn northwest of 3-16. A circular patch of ground appears slightly darker than the surrounding area. In the center of this patch a sprinkler (circular irrigation) can be observed watering the corn. Additional sprinklers can be seen elsewhere in the cornfield as indicated on the panchromatic image overlay.

Figure 2.30: Ferry on Willamette River at Buena Vista, looking east.

Figure 2.31: Mature corn stalks with farm buildings in background.

Radar (Figure 2.32)
A number of features are detectable on the radar image of the Willamette River at Buena Vista. The most striking is the Willamette River itself. The smooth surface of the water acts as a specular target for the X-Band electromagnetic energy. The energy is simply reflected away from the antenna, with the angle of reflection equal to the angle of incidence. Since no energy is returned to the receiving antenna, the river appears black on the image.

Another prominent feature on the image is the distinction between cropland and smaller rivers such as the Luckiamute and the Santiam. The abrupt relief change from the low-lying crops to the taller trees that border the river produces a strong return, expecially on the side closest to the radar antenna. A shadow effect on the side opposite the antenna also aids in the delineation of the river's course.

Differentiation between cropland and burned fields is possible in some cases since the lack of vegetation on the burned field produces a weaker return which makes them appear dark. The cropland has a brighter and more speckled appearance. The orchards to the north of Buena Vista give

a relatively strong return because of the change in relief from the surrounding cropland. The town of Buena Vista gives a strong radar return due to the buildings which act as corner reflectors. Also the metal roofs of some of the buildings give strong returns because of their electrical properties. Numerous other isolated buildings outside the town give strong returns enabling them to be detected easily.

Thermal Infrared (Figure 2.33)

On the thermal IR image the patchwork nature of this agricultural area is somewhat less apparent. However, the outlines of some of the fields are marked by the light signature of the warmer dirt roads. Asphalt roads are even lighter in tone since they have a higher radiant temperature. Thus asphalt and dirt roads can be differentiated; examples of each are labeled on the image overlay.

Most of the agricultural fields give similar signatures and therefore the corn is not distinguishable from the other drier crops. The field which appears burned on the panchromatic image has a slightly darker signature than the other fields on the thermal IR image; possible because there is no insulating vegetation on the burned field. Within the corn field the circular patch of ground being watered in the panchromatic image appears slightly darker in the TIR image. It is probable that this patch of ground remained damp and appears cooler than the surrounding area due to the effects of evaporative cooling.

Areas of natural vegetation (trees) have a slightly warmer signature than the agricultural areas and this allows them to be distinguished on the thermal IR image. Many of these areas are along the river. The ferry is detectable as a dark spot along the western bank of the river.

In the town of Buena Vista a number of objects with dark signatures can be detected. These are buildings with metal roofs (Bm). It will be noticed, that some buildings are not detectable on the thermal IR image but are detectable on the panchromatic image. These buildings do not have metal roofs and are probably residential homes.

Two ground data collection sites (3-15 and 3-16) are present on the TIR image and are indicated on the overlay. Thirty-five mm photos of these sites are included here and described in the section on panchromatic interpretation.

Unfortunately, soil moisture content data and radiant temperature data are not available for these locations due to lack of access at time of collection because of ferry closure at night.

CROSSROADS AT TARTAR TEST SITE

Introduction

A variety of terrain and cultural features are present at this location in the northwest corner of the test area. Included are forested foothills of the Coast Range, logged areas, streams and rivers, residential homes, roads, railroads, and cropland and pasture.

Panchromatic (Figure 2.34)

The panchromatic image shows a distinct boundary between the dark-toned forested region (T) in the south and west, and the light-toned agricultural area of cropland and pasture (C) in the north and east. Resolution is good enough that individual trees can be distinguished except in the more densely forested parts. In the middle of the image is an area of the deciduous forest that has been clear-cut. To the northeast of this is an area only partially logged where a number of isolated trees remain. The use of a stereoscope shows the variation in elevation between the lower agricultural area and the more elevated forested region. The Luckiamute River, several roads, and the Valley and Siletz Railroad transect the area and are clearly visible on the image. Numerous buildings are also found within the area of the image, mostly along Suver Road.

Ground data collection site 3-2, located near the cross-roads at Tartar, is shown on the interpretation overlay. A 35 mm photograph (Figure 2.35) looking northwest shows an agricultural field burned to the ground. In the background are a building and some trees indicated on the image as H. The field directly west of 3-2 is completely charred in the 35 mm photograph, however, on the panchromatic image, the field has been partially plowed under. Thus the plowing of the field must have occurred sometime between the time of ground data collection and the collection of aerial photography.

Figure 2.35: Burned agricultural field with farm buildings and trees in background.

Radar (Figure 2.36)

Several topographic and cultural features are detectable on the radar image of this area. There is a sharp distinction between the low-lying cropland (C) and the more elevated forested areas (T). Several drainages are detectable in the region around Tartar, namely the Luckiamute River, Peterson Creek, and the Jont Creek drainage. These are detectable because of the abrupt change in relief between the relatively flat cropland and the trees that border the rivers. In the more elevated forest areas, however, it is not the trees which produce the strong radar return, but rather the topography. It is very difficult to delineate where cropland stops and forest begins. But it is easy to locate where the hills meet the flatter valley portions. Note that the logged area to the southwest of Tartar is not detectable on the radar image.

A number of burned fields are detectable because their lack of vegetation makes them appear as specular targets to the radar beam. Hence they appear dark on the image. Roads within the area are not distinguishable at the low resolution of this imagery. However, the Valley and Siletz railroad is detectable. The strong return may be the result of the electrical properties of the metal tracks. At Tartar, the strong return is produced by the buildings in the town as a result of the electrical properties of the metal roofs and the behavior of the buildings as corner reflectors.

Thermal Infrared (Figure 2.37)

Several features are detectable on the thermal IR image. Asphalt roads can be differentiated from dirt or gravel roads, both giving warmer signatures relative to the surrounding fields. The Valley and Siletz Railroad track can be distinguished as a warm linear feature trending generally northeast across the image. The warm signature is probably due to the bare gravel and dirt along the track being covered with oil. Rivers and other minor drainages are detectable with their warm signatures caused by the water and the dense vegetation along their courses. The Luckiamute River and the Jont Creek drainage are labelled on the interpretation overlay. Several buildings give dark signatures and therefore must have cool metal roofs. Other buildings, visible on the panchromatic image, are not as easily detected on the thermal IR image because their roofs are made out of a material with thermal properties similar to that of the surrounding area.

Most of the cropland and pasture give the same thermal response, however some of the fields appear slightly warmer possibly because the insulating vegetation has been cut away. Forested portions have a slightly warmer signature than the agricultural area and thus the two can be distinguished on the image. The forested area that has been

partially logged contains several isolated trees which are detectable as distinct individual trees. These can be seen in the southwest corner of the image and on the interpretation overlay. A soil sample taken at ground data collection site 3-2 in the burned field west of the road contained 7.8% moisture, however no radiant temperature data was obtained.

Spot Density Measurements

Spot density measurements were taken from various site materials from throughout the test area by the use of positive transparencies of the thermal infrared imagery. The MacBeth Spot densitometer was calibrated using the Kodak gray scale wedge. Various materials were measured to identify various film densities which correspond to the various radiant temperatures imaged by the thermal mapper. The results are tabulated in Table 2.1 below.

MATERIAL	DENSITY	TEST SITE LOCATION	FRAME NUMBER
Gravel Road	.76	Independence Road Site 2-5	165
Gravel Road	.78	Willamette River-Traverse 2	203
Gravel Road	.82	Corvallis	207
Asphalt Road	.80	Traverse 2-Willamette River	203
Asphalt Road	.78	Corvallis	207
Asphalt Road	.75	Highway 20 Corvallis	203
Asphalt Road	.76	Highway 20, Corvallis	203
Tennis Court - Clay	.78	Oregon State University	206
Tennis Court-Coated Asphalt	.74	Oregon State University	206
Asphalt Parking Lot	.84	Oregon State Parker Stadium	206
Gravel Lot	.72	Oregon State Parker Stadium	206
Astroturf	.84	Oregon State Parker Stadium	206
Grass	.82	Western View Inter. School	206
Metal Building	1.05	Buena Vista, Site 3-2	168
Water	.79	Luckiamute River	167
Water	.74	Pond-Soap Creek & Hwy. 99	148
Stadium Bleachers-East	.75	Oregon State University	206
Stadium Bleachers-West	.82	Oregon State University	206
Clear Cut Area	.94	North of Corvallis	208
Forested Area	.87	North of Corvallis	208
Burned Field	.90	Buena Vista	147
Burned Field	.92	Buena Vista	147
Bare Ground	.83	Soap Creek and Hwy. 99	148

Table 2.1 -- Spot Density Measurements by a MacBeth Spot Densitometer for specific materials imaged on an 8-14 micron thermal mapper of the Willamette Valley test site.

3 - LANDSAT

Processing and Interpretation

The Landsat image of the Corvallis, Oregon test area was collected on 19 August 1980 (ID# E22036 - 18204). This is the same day that the panchromatic photography and the thermal infrared imagery were collected. The simultaneity of these images provides a unique data set for analysis. Similarly planned operations have often been hampered by weather or cloud cover problems. The Landsat imagery was sent directly from EROS at Sioux Falls, South Dakota, to the processing facility of ESL, Inc., Sunnyvale, California. The computer compatible tapes were accompanied by a 1:250,000 scale print of band 5 plus negatives of bands 4, 5, 6 and 7. The processing consisted of a series of steps which included: 1. reformatting of the Landsat scene. 2. Subsection of the scene to extract the study area of 512 by 512 pixels. At this point a color composite was programmed on the IDIMS (Interactive Digital Image Manipulation System) system and a visit was made to ESL by the ESCA-Tech principal investigator and project geologist. All of the ground truth information was taken to this meeting for use in detailed classification of the image.

The ESL applications scientist brought the Landsat image up on the De Anza advanced color image processor as a color composite image (Figure 3.1, next page). At this point the principal investigator and computer programmer worked together to train the classifier. A series of terrain features visited in the field were evaluated on the processor. Trees, shrubs, crops, urban areas, soils, rocks, rivers, streams and open fields were all viewed and classified. Each feature or set of features was given a color-code. The entire test area was then viewed and corrections made as necessary to determine classification accuracy. The entire test area was reclassified numerous times until a high degree of correlation between the color code and actual land use was established. When each party was satisfied the final coded land use classification was made (Figure 3.2, next page). The original screen image was saved in digital format for making a master color negative of the color coded classification.

The class descriptions that accompany Figure 3.2 as an explanation were defined at this point. A comparison plot was constructed by the IDIMS system for use in the final classification. Groupings of reflectance levels from Bands 5 and 7 were plotted in graphic format (Figure 3.3, next page). The 25 classes shown on this graph were found to contain several groupings. In other words, grain crops fell into three categories for small leafed crops and two groups for large leafed crops.

Figure 3.1 Landsat Color Composite - Corvallis, Oregon Area
ID # E 22036-18204
The city of Corvallis is in the lower center, adjacent to the Willamette River which flows northward towards the top of the image.

Figure 3.2 Land Use Classification of Landsat Image ID # E 22036-18204

Color Code	Land Use
Dark Red	pasture and grain crops
Red	cut and small leaf grain
Tan	row crops
Black	open water, burned fields
Gray	urban, commercial areas, roads
Dark Green	coniferous trees
Olive	deciduous-coniferous mixed
Yellow	corn and grasses
Dark Blue	riparian and bottomland
Orange	shrub and deciduous plants

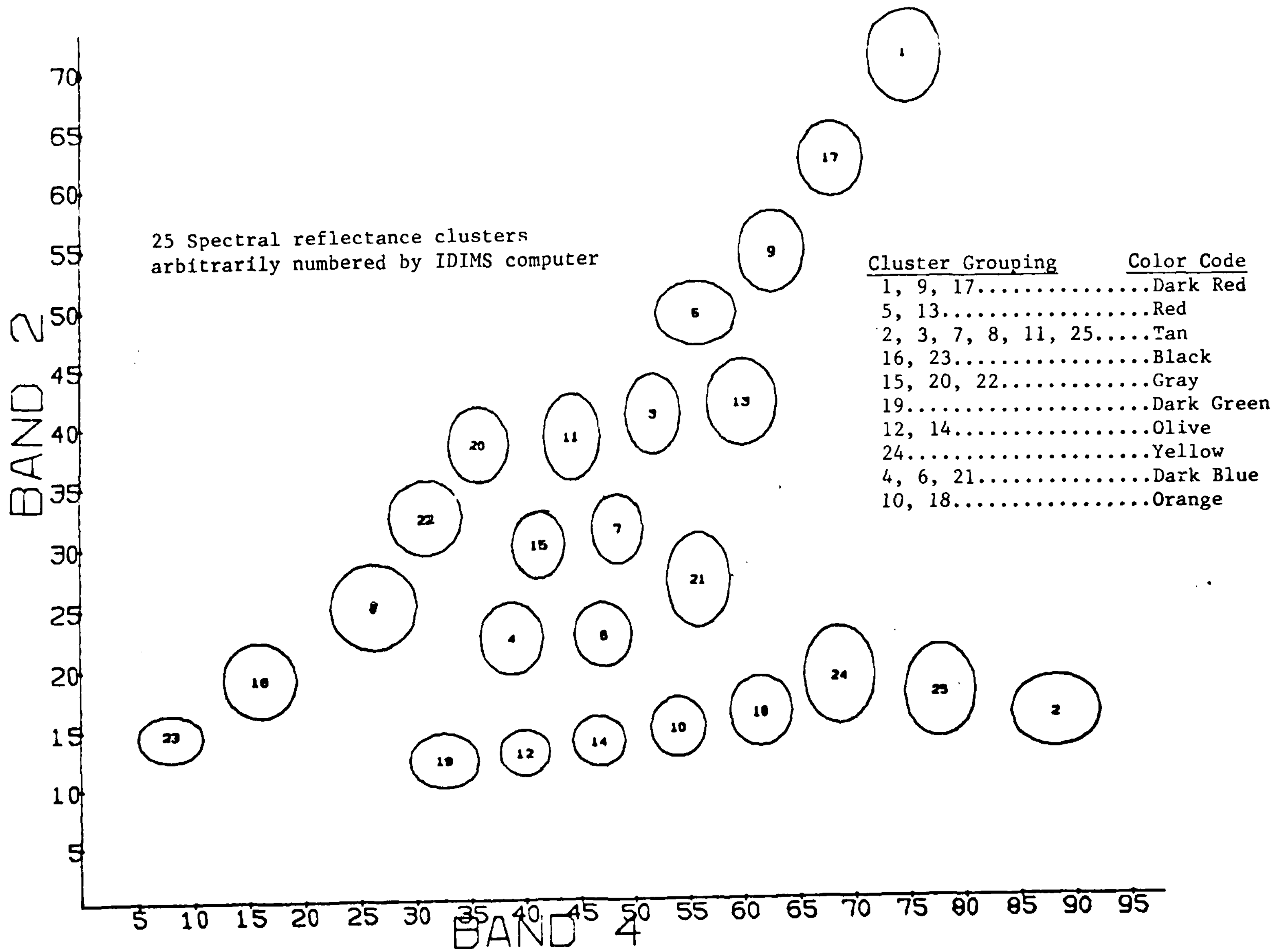

Figure 3.3 Landsat Compare Plot for Bands 2 (5) and 4 (7)
ID # E 22036-18204

The reason for this is variation in soil, moisture, planting schedule, look direction and crop type. It should be noted that many of the classifications are mixed. For example, the trees that cover the Coast Range foothills were both coniferous and deciduous. In some cases each type was segregated but often they were mixed. For this reason the labels given to the classification colors are sometimes mixed in nature to most correctly address the defined feature. By using the simultaneously collected ground truth, aerial photography and Landsat imagery, the investigators had a distinct advantage in this overall procedure.

Equipment: IDIMS (Interactive Digital Image Manipulation System)

The IDIMS system used to process the digital multispectral data from the Landsat scene was developed by ESL Incorporated. The basic display is on a 58 centimeter, high-resolution color monitor. The display consists of 512 by 512 viewable elements in one image, with three or more complete 8-bit-resolution images stored in the display. A trackball-driven cursor is used for point selection and real time intensity mapping, plus true-color and black-and-white image display with a 64 pseudo-color option.

IDIMS functions are designed to accept various image data formats and numeric representations. Many processing functions will handle both line by line and band by band organization of multispectral data. Additionally, most functions will support images of arbitrary size. All image input and output is handled by IDIMS system routines. The system input for the IDIMS configuration is designed to accept computer/compatible digital tapes (CCT's). Photographic images are converted to digital form by utilizing an auxillary input scanning device. System output involves line printer maps and photographs of the video monitor in typical hardcopy form. For high resolution photographic copies of processed imagery, a digital image record can be interfaced with IDIMS quite easily.

The unique floating point array processor and minicomputer combination performs a maximum-likelihood classification for a four band, 512 X 512 image into 50 classes in less than 260 seconds. The minicomputer memory is expandable to 512 kilobytes and disc storage is expandable to 1200 megabytes on a single controller.

The basic system is fully interactive. The user interacts with IDIMS through a powerful command language or menu. The menu mode allows the IDIMS analyst to select processing and display functions from lists presented at the analyst's terminal. The user merely selects from the library the processing algorithms he wishes to apply to a problem, then, by committing an image to on-line storage or by recalling one already stored, he keys in the manipulation commands. The results, displayed on a cathod-ray tube for evaluation, may be stored in whole, in part, or deleted before processing to the next algorithm. This process is repeated until the desired improvements or goals are achieved.

4 - FIELD PROCEDURES

Imagery Data Collection

The aircraft utilized in the imagery collection portion of this project was a Mohawk OV-ID flown by the Oregon Army National Guard. The Landsat data was obtained by the NASA Landsat satellite. The sensor system and imagery specifications are summarized below. All times and altitudes (except for Landsat) are according to the O.A.N.G. flight logs.

	Date	Time	Altitude
Radar	13 Aug. 1980	1100 Hrs.	2293 meters (7500 feet)
	14 Aug. 1980	0400 Hrs.	2293 meters (7500 feet)
	18 Aug. 1980	1100 Hrs.	2293 meters (7500 feet)
Thermal IR	13 Aug. 1980*	0400 Hrs.	Classified
	19 Aug. 1980	2300 Hrs.	Classified
Panchromatic	19 Aug. 1980	1100 Hrs.	3058 meters (10000 feet)
Landsat	19 Aug. 1980	1000 Hrs.	918 kilometers

* - not utilized, scanner malfunction. All other data was utilized.

NOTE - annotation block on panchromatic imagery is incorrect. Annotation from last flight (May 18) was inadvertantly left on the block.

Radar

APS 94E X Band, SLAR
Resolution, near range: 4 meters
Resolution, far range: 12 meters
Swath width: 25 kilometers

Thermal Infrared

(All specifications classified)

Panchromatic

KC-IB Fairchild Aerial Camera, focal length 21.25 cm
Format: 9"X9", 450 frames possible
Forward Sparing: 60% overlap
Side Sparing: 20% sidelap
Distance between flight lines: approximately 4 kilometers

Landsat

Identification # E-22036-18204-5
Ground Resolution Cell : 79 by 79 meters

The film from the airborne camera and scanner systems was processed by the O.A.N.G. at their Salem, Oregon, facility under the supervision of Sgt. Crosby. Processing was done at 5 feet per minute using an Oscar Fisher Co. EH48 processor with AF (Armed Forces) D4 high contrast developer at 33°C.

A calibrated step wedge was exposed on the thermal infrared scanner film for use in densitometer measurements. TIR and panchromatic strip prints were made on an EN 100 Roll Printer at 5 feet per minute. Close calibration of all steps were insured by utilizing the standard procedures constantly employed at the O.A.N.G. facility. However, the panchromatic imagery was reprinted by Teledyne Geotronics of Long Beach, California because of the overexposure of the prints supplied by the O.A.N.G.

Ground Data Collection

Ground truth information was collected on 13 August 1980 by three ground teams consisting of two scientists each. Data was collected at 1.6 kilometer intervals along three separate traverses designated Traverse 1, Traverse 2, and Traverse 3. These are described briefly below.

Traverse 1 - Corvallis to Albany - 26 kilometers (approximately)

This southernmost traverse begins west of Corvallis, passes through Corvallis, northward along Highway 20 to the Agricultural Test Station of O.S.U., then eastward along the Willamette River, and into Albany. The major features of interest are the urban areas of Corvallis and Albany, the Willamette River, and the Hyslop Agricultural Test Station. Thus a wide variety of terrain types are encountered.

Traverse 2 - Soap Creek Valley to Willamette River - 32 kilometers (approx.)

Soap Creek Valley is located in the foothills of the Coast Range. From here the traverse passes through coniferous forests, and enters the Willamette Valley near the Fulda Gap look-alike. A short side traverse to the northwest leads to Oak Hill where the O.A.N.G. has positioned several Russian Land Mine look-alikes. The traverse then continues to the east past Camp Adair Military Reservation toward the Willamette River. Thus highly different vegetation and soil types are encountered because of changes in geology, elevation, and precipitation.

Traverse 3 - Maple Grove to Sidney - 26 kilometers (approximately)

This northernmost traverse passes through several small towns and large tracts of agricultural fields. Variations in both natural and agricultural vegetation are encountered. The traverse also crosses both the Luckiamute and Willamette Rivers. At the Willamette the traverse crosses the river via ferry and continues through agricultural land to its end.

The location of the three traverses, the data collection sites and the eight interpretation areas are indicated on Figure 4.1 (next page). The first digit of the site identification number is the traverse (1, 2, or 3), and the second is the site along that traverse (1, 2, 3 ...). Interpretation areas are labelled.

Radiant temperature measurements (for traverse 1 and 2) and collection of soil samples (all 3 traverses) took place between 0400 and 0600 hours, 13 August. Instruments used for temperature measurements included a Barnes Precision Radiation Thermometer (PRT-5) and a handheld Teletemp Radiation Thermometer. Calibration of these two instruments was achieved with a common uniform heat source, the surface of the swimming pool on 9th Street in downtown Corvallis. The PRT-5 registered 24.0°C, the Teletemp 23.0 to 24.0°C, and a handheld mercury-filled thermometer 24.0°C. The radiant temperature measurements for traverses 1 and 2 are listed in Table A.1 of the Appendix.

Soil samples were collected for an analysis of soil moisture content. The procedures for the moisture content evaluation are described in detail in the section under Laboratory Procedures, and the results are given in Table A.2 of the Appendix. Meteorological data for the test area at the time of ground data collection was obtained from the Hyslop Field Laboratory - Oregon State University Agricultural Test Station located near Granger. The data are given in Table A.3 of the Appendix.

From 1000 to 1200 hours data collection included the following: exact location of collection site on U.S.G.S. topographic map, identification and description of terrain parameters, identification of vegetation, description of cultural features, and 35 mm photography to record overall terrain features.

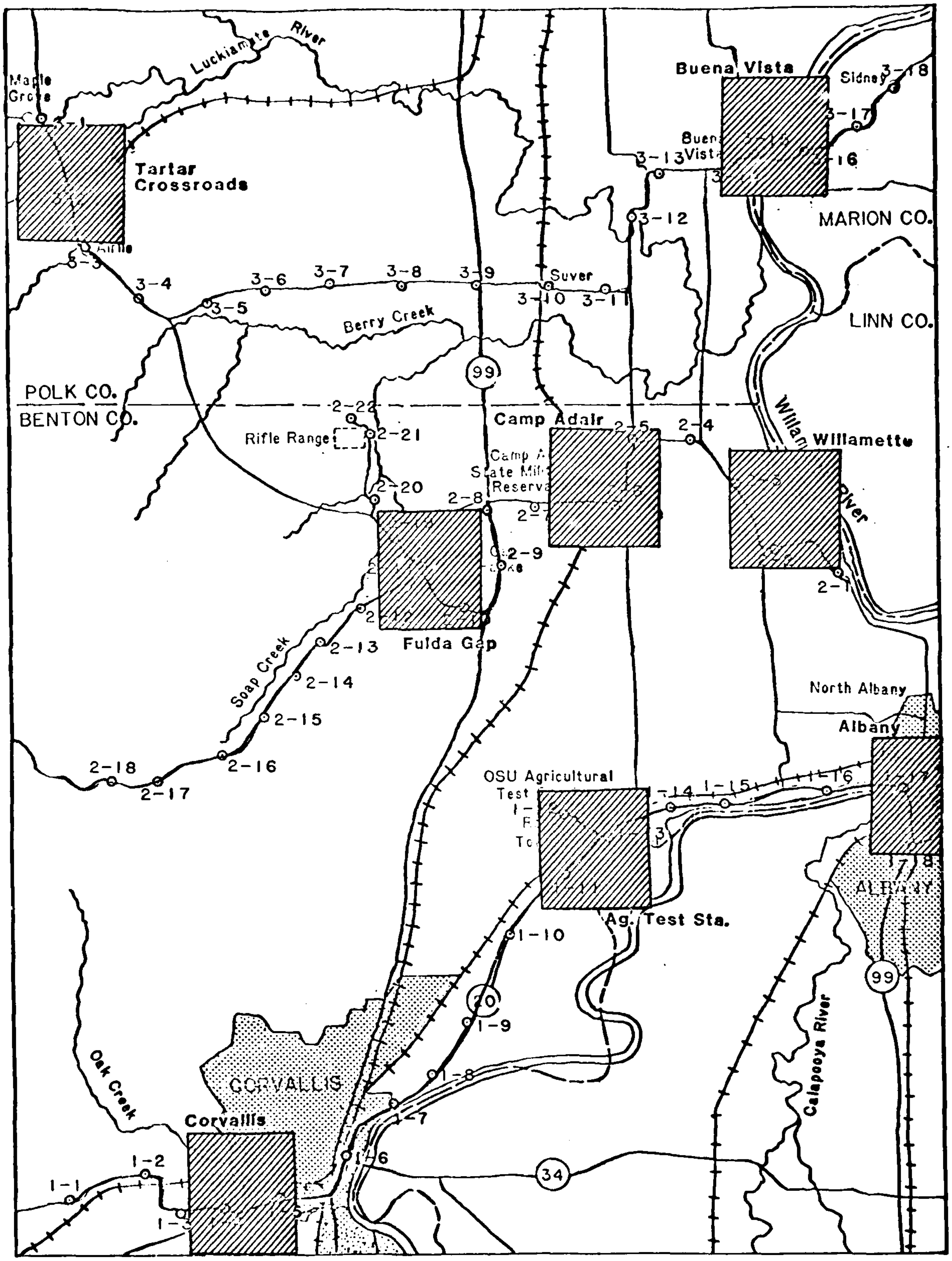

Figure 4.1 : Ground Data Collection Sites and Interpretation Areas

5 - LABORATORY PROCEDURES

Soil Moisture Content Evaluation

Collection of soil samples took place between 0400 and 0600 hours, 13 August 1980. The samples were transported in air tight containers to the Soil Science Laboratory at Oregon State University. Measurements of the mass to the nearest hundredth of a gram were recorded before and then after 20 hours in a drying oven. Subtracting the mass of the containers when empty yielded the initial mass of the sample and the mass of the moisture lost. From these the percent moisture content was calculated as follows:

$$\% \text{ Moisture} = \frac{\text{mass of moisture content}}{\text{mass of initial sample}} \times 100\%$$

The results of this procedure are given in Table A.2 of the Appendix.

Soil Emissivity Evaluation

It is known that moisture present in a soil will cause a lower radiant temperature than dry soil. This is the result of evaporative cooling (Sabins, 1978). An experiment was conducted to determine the percent soil moisture required to change the radiant temperature of soil a significant amount so that it can be recorded or detected by thermal infrared radiometers.

The diurnal temperature plot for varying soil moistures (Figure 5.1, next page) is a compilation of the data collected. It is obvious that at the peak solar time the maximum radiant temperatures are recorded. The interesting and most crucial part of this plot, however, is at pre-dawn and post-sunset hours. This is when the most rapid change in radiant temperatures occurs due to the warming or cooling of an object by the initial influx of the sun's energy on the object, or the removal of this incident energy from the object. The complexity of the graph at this point requires a careful study of the soil temperature tables (Table 5.1) and the weather conditions that existed for that particular time period (Table 5.2). Figure 5.2 is a 35 mm photograph of the soil samples. Sample 1 has 11% moisture content, sample 2, 0%, sample 3, 16%, sample 4, 29%, sample 5, 20%, and sample 6, 5%.

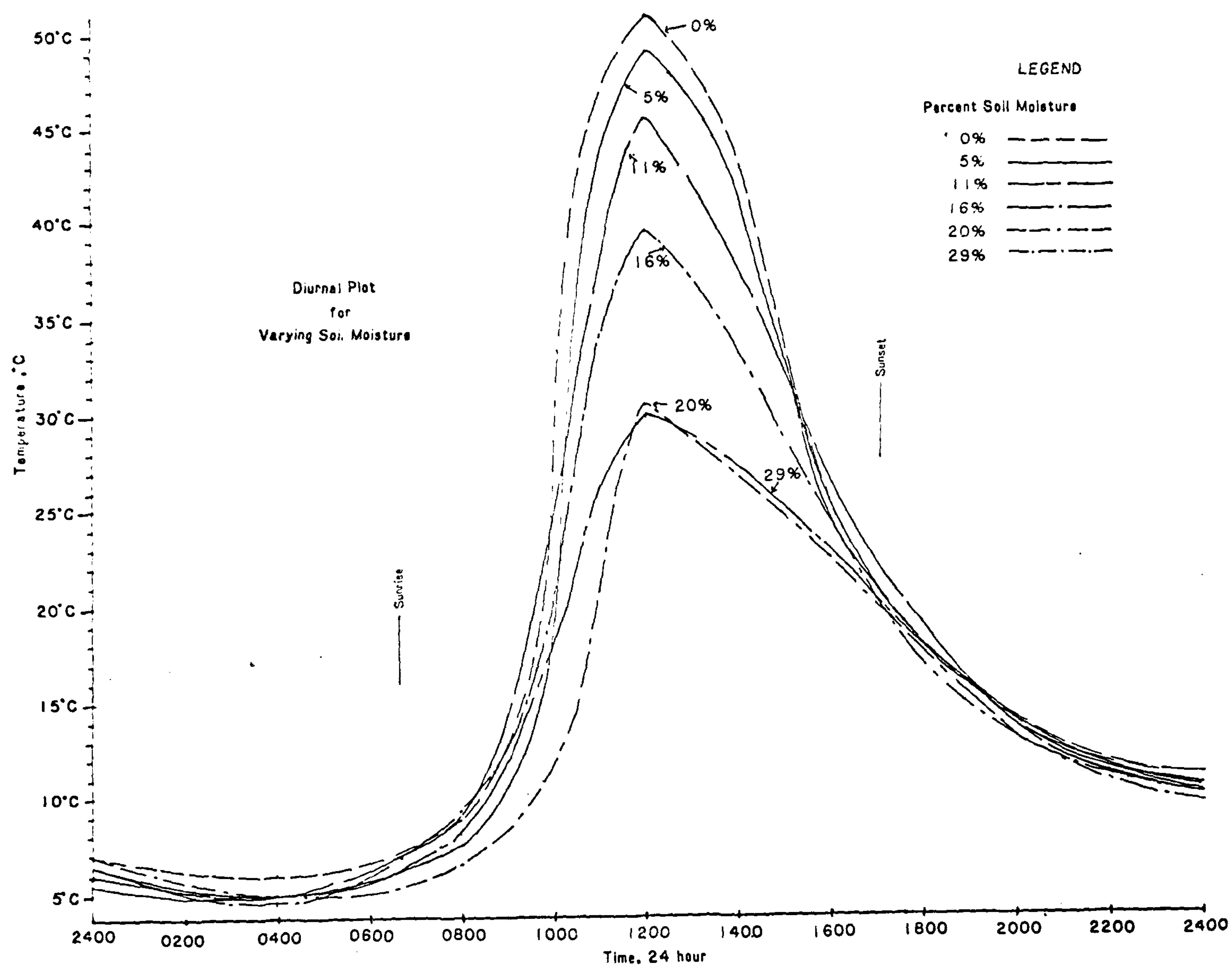

Figure 5.1 -- *Diurnal Plot for Varying Soil Moisture*

Time	Moisture Content					
	0%	5%	11%	16%	20%	29%
2400	7.0°C	5.5°C	6.0°C	6.5°C	7.0°C	6.5°C
0400	6.0°C	5.0°C	5.0°C	4.5°C	5.0°C	5.0°C
0800	8.75°C	7.5°C	9.0°C	7.5°C	6.5°C	8.0°C
1200	51.0°C	49.0°C	45.5°C	39.5°C	30.5°C	30.0°C
1600	25.0°C	24.5°C	25.0°C	24.5°C	22.5°C	23.0°C
2000	13.5°C	13.5°C	13.5°C	13.0°C	13.0°C	14.0°C
2400	11.0°C	10.5°C	10.0°C	9.5°C	10.0°C	10.0°C

Table 5.1: Diurnal Radiant Temperatures

Time	Air Temp.	Time	Air Temp.	Time	Air Temp.	Time	Air Temp.
2400	15.5°C	0600	12.7°C	1200	30.6°C	1800	20.6°C
0100	14.4°C	0700	13.8°C	1300	31.1°C	1900	21.6°C
0200	13.3°C	0800	18.8°C	1400	31.6°C	2000	20.0°C
0300	13.8°C	0900	22.8°C	1500	30.6°C	2100	17.8°C
0400	13.8°C	1000	25.6°C	1600	28.3°C	2200	17.2°C
0500	13.3°C	1100	29.4°C	1700	24.4°C	2400	16.1°C

Table 5.2: Weather conditions at time of experiment.

SAMPLE	WEIGHT OF SOIL + PAN	WEIGHT OF SOIL + PAN + INITIAL MOISTURE	WEIGHT OF SOIL + PAN + MOISTURE AFTER 24 HRS.	WEIGHT OF SOIL + PAN AFTER 10 HRS. IN OVEN	% SOIL MOISTURE	% SOIL MOISTURE AFTER 24 HOURS	DIFFERENCE IN MOISTURE CONTENT AFTER 24 HOURS
1	260.0 gr.	279.9 gr.	255.5 gr.	252.1 gr.	11.0%	1.3%	- 9.7%
2	260.0 gr.	260.0 gr.	263.7 gr.	260.4 gr.	0	1.3%	+ 1.3%
3	262.0 gr.	300.9 gr.	263.1 gr.	259.0 gr.	16.2%	1.6%	- 14.6%
4	263.0 gr.	337.0 gr.	265.3 gr.	260.3 gr.	29.5%	1.9%	- 27.6%
5	258.2 gr.	307.0 gr.	260.8 gr.	255.8 gr.	20.0%	1.9%	- 18.1%
6	263.0 gr.	273.8 gr.	264.0 gr.	261.1 gr.	4.9%	1.1%	- 3.8%

Table 5.3: Data used to derive Soil Moisture Content of emissivity evaluation samples.

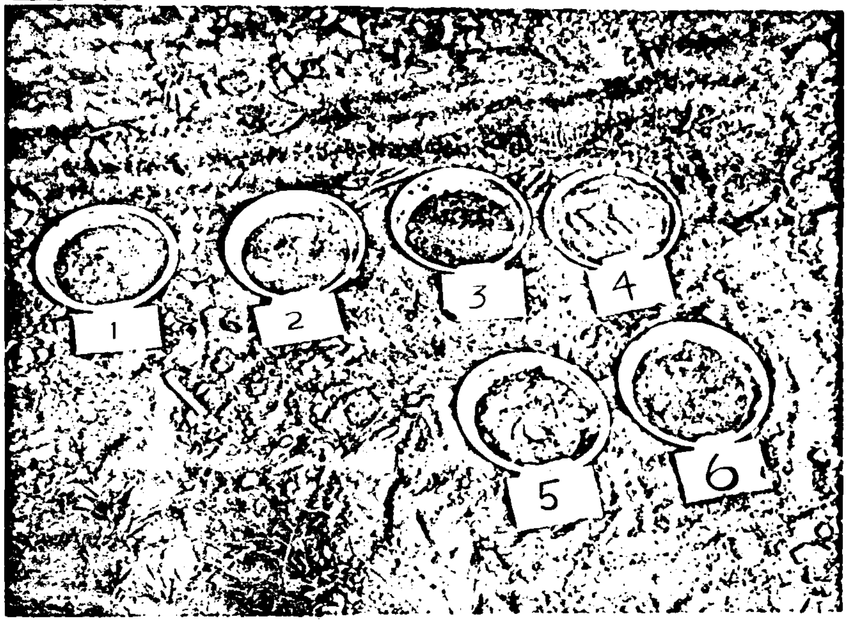

Figure 5.2: Soil samples used during evaluation of soil emissivity.

Radiant temperature measurements were taken every four hours over a continuous 24-hour period with a Barnes Precision Radiation Thermometer (PRT-5). Moisture content was established with six control samples at 0%, 5%, 11%, 16%, 20% and 29% moisture content. These samples were weighed and recorded for use in their moisture content calculations. After temperature measurements were conducted over the 24-hour period, the samples were weighed again. The samples were then allowed to dry for ten hours at 135^{o}C in an oven. At the end of ten hours the samples were removed and weighed a third time. The weight of the moisture lost divided by the dry sample weight multiplied by 100 gives the percent soil moisture of each sample (Table 5.3).

The initial temperatures were recorded approximately one hour after being exposed to the outside environment. These temperatures were approximately 4^{o}C cooler than the temperatures taken exactly 24 hours later. This is attributed to the change in air temperature and the evaporation that occurred during that 24-hour period. Initial weights

were recorded prior to setting them into the experimental environment. Results from the evaporation for 24 hours show a general loss of moisture to about 1.5% (average). The temperatures taken at the end of the experiment, therefore, represent a considerably drier soil. Variation in temperature at the end of the experiment is attributed to the surface condition of the soil itself. Samples containing 16%, 20% and 29% moisture content had formed hard crusts. The samples of 0%, 5% and 11% were unconsolidated. The 1.5°C temperature variance at the end of the 24 hour period represents a 0.8% moisture difference.

In Figure 5.1 it can be deduced that with greater soil moisture the temperature variation becomes much smaller with time. That is, the difference between maximum and minimum radiant temperatures over a 24-hour period are less with increasing soil moisture. Also, temperature increases tend to be much less dramatic near sunrise and sunset when moisture content is greater. Temperature variations within the predawn/post-sunset hours are minute and require detailed temperature measurements.

After about 30 minutes outside, samples containing 0% soil moisture had the greatest temperature difference, 1.5°C. The 16%, 20% and 30% samples were warmer than the dryer samples due to the excessive amount of water present. In the 20% and 29% moisture samples, the soil was extremely muddy. At 16% moisture content the soil was extremely damp. These large amounts of water contributed to the warm radiant temperatures. After four hours the greatest temperature difference was between 0% and 16% moisture content. The difference was again 1.5°C. The other soils (5%, 11%, and 29%) had the same temperature. This is probably due to the water and soil temperatures attaining equilibrium with the air temperature.

At 0800 hours, just after sunrise, a wider temperature difference begins to develop. This is between 29% and 0% and 5% soil moisture. The temperature difference was 2.5°C. This variation represents the initial effects of evaporative cooling on the samples. Direct sunlight did not occur until 1030 hours and only lasted until 1530 hours, a total of five hours.

At the peak solar hour (1200 hours) the temperatures directly corresponded to the amount of moisture present. A difference of 20.5°C was observed between the 0% and 29% moisture content. This first half of the experiment therefore shows a direct relationship between moisture content and radiant temperature.

As the sun descends toward the horizon, the radiant energy incident on the sample becomes less intense and temperatures begin to fall rapidly. At 1600 hours a maximum temperature difference of 2.5°C exists between the 20% sample and the 0% sample. This indicates that the moisture is still evaporating and keeping the moister samples cooler.

Approximately three hours after sunset maximum temperature variation is only 1.0°C. This is probably the result of the samples becoming more or less equal in moisture content and therefore, the surface temperature becomes largely dependent on the condition of the surface and its ability to evenly absorb moisture from the cool damp air. Because the soil contained a large amount of clay, a hard pan or cursty surface developed in the very moist samples. This hard crust did not allow the soil to radiate energy evenly and therefore resulted in a non-correlative temperature reading.

The temperature difference at 2400 hours was 1.5°C. The warmest being the dry sample and the coolest representing the 16% moisture sample. As a whole this temperature reading was approximately 4.0°C warmer than temperature measurements made 24 hours previously. This difference in radiant temperature can be attributed to the excessive loss of moisture in the samples. Evaporative cooling does not play such an important factor in these last measurements as it did in the beginning. The 16% moisture sample was the coolest because the sample was loose and therefore moisture still present was evaporating and still contributing to its cooler signature. The 20% and 29% moisture samples had hard crusts that prevented any significant evaporative cooling.

In conclusion, by examining Tables 5.1, 5.2, and 5.3, a variation in soil moisture greater than 16% causes the greatest variation in radiant temperatures during predawn and post-sunset hours. If we look at only temperatures near the beginning of the experiment, we can observe a gradual decrease in temperature with increase in moisture content up to between 11% and 16% moisture content. At 16% or greater, water acts as insulation for the soil and causes it to maintain a somewhat uniform temperature.

6 - BACKGROUND INFORMATION

Introduction

The following sections contain general background information on the test area collected prior to and during the preparation of this Reference Image Set. Its inclusion here is to serve as a source of reference for a better understanding of the various physical and cultural features of the test area. These features include physiography, geology, hydrology, climate, soils, land use, and cultural features. The sources utilized and their authors are indicated within the text.

Physiography

The test area includes portions of two physiographic provinces of Oregon - the Willamette Valley and the Coast Range, Figure 6.1, next page. The Willamette Valley is a broad structural depression oriented north-south between the Coast Range on the west and the Cascade Range on the east (Franklin and Dyrness, 1973). The Valley is approximately 200 kilometers in length, extending from the Columbia River to Cottage Grove where the two mountain ranges converge. Topographically, the Valley is characterized by broad alluvial flats separated by groups of low hills. The valley floor has a very gentle north facing slope with elevation decreasing from 129 meters at Eugene to only 50 meters at Salem 130 kilometers to the north. As a result, the Willamette River is a slow-moving stream with numerous meanders. This fact, along with the large quantity of alluvium in the valley indicate that the valley is a relatively mature feature.

The Coast Range province extends from the middle fork of the Coquille River in Oregon northward into southwestern Washington (Franklin and Dyrness, 1973). The southern section of the range is topographically mature with steep slopes and sharp ridges, however, the proportion of steep slopes decreases in the northern section. Mountain passes are generally located on the eastern border of the range due to faster rates of headward erosion by the numerous westward-flowing streams.

Mary's Peak, elevation 1,249 meters, is the highest peak in the Coast Range, and is located about 25 kilometers to the southwest of Corvallis. However, elevations of the main ridge summits range from only 450 to 750 meters.

Within the test area elevations range from a high of 700 meters in the foothills of the Coast Range to a low of 50 meters along the Willamette River. The average elevation of the Valley floor in the area is approximately 65 to 35 meters although it is gently rolling rather than totally flat. The Valley is broken by occasional prominent low hills and buttes. Along the Willamette River, numerous meander scars are apparent topographically; some of which still contain water.

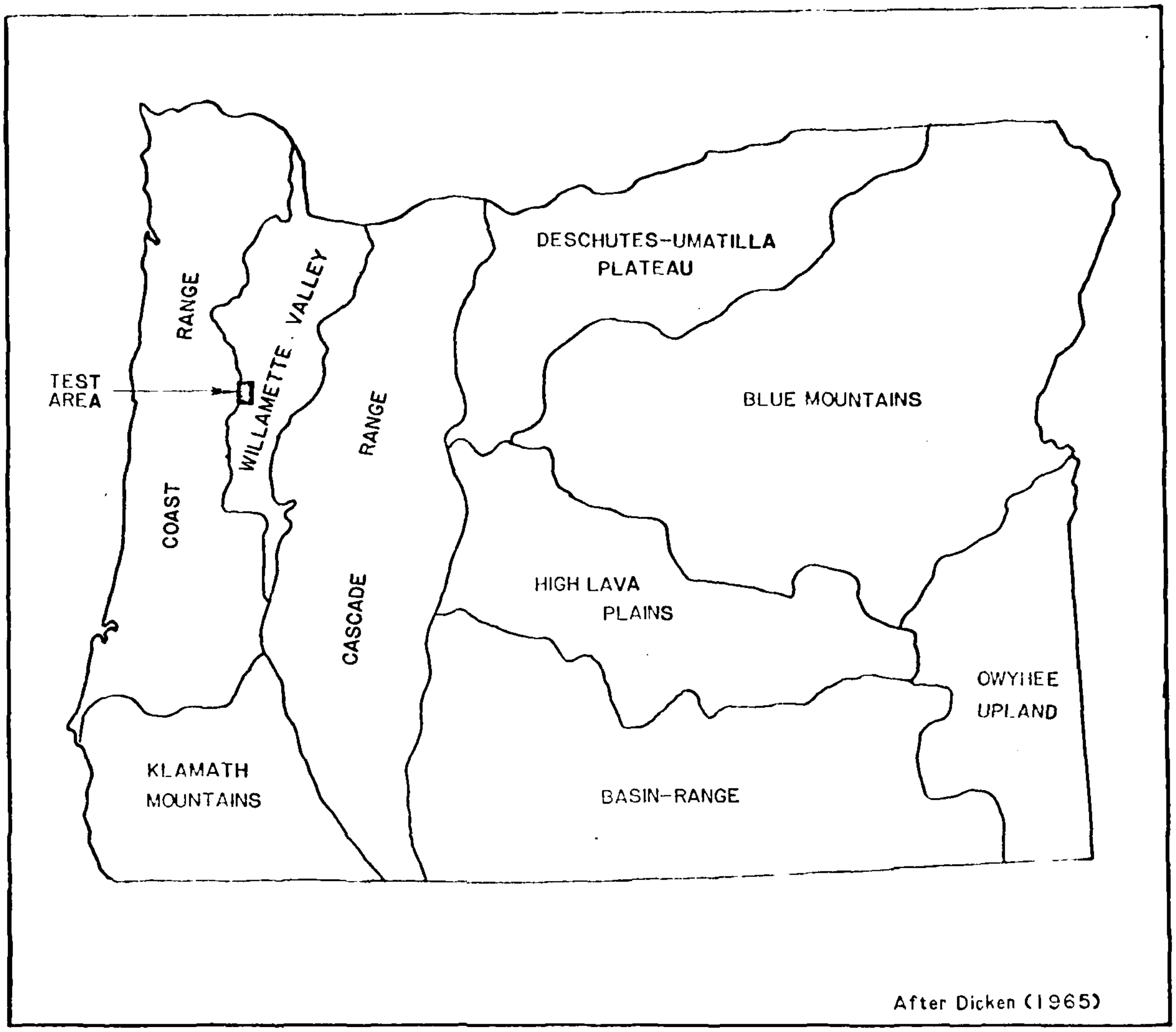

Figure 6.1: Physiographic Provinces of Oregon

Geology

The test area of this study includes parts of two physiographic provinces, each with distinct geologic characteristics and histories. In the western portion of the area are the foothills of the Southern Coast Range. On the east is the Willamette Valley. The western border of the Willamette Valley near Corvallis consists of a variety of sedimentary and volcanic rocks. These rocks represent eastward extensions of Coast Range formations that presumably go beneath the Valley almost to the margin of the Cascade Range (Baldwin, 1976).

The gologic history of the southern Coast Ranges began during early Eocene time with deposition of submarine pillow basalts (Franklin and Dyrness, 1973). Later in the Eocene, the vast sedimentary beds of the Tyee formation were deposited under marine conditions. The Tyee formation is largely composed of rhythmically bedded, tuffaceous and micaceous sandstone, and occurs through the southern Coast Range. Scattered igneous intrusions, largely gabbro, occured during the Oligocene and cap many of the most prominent peaks. During the Miocene, localized depositions of both sedimentary and volcanic rocks occurred.

Baldwin (1976) states that the basalt is particularly well exposed at Coffin Butte, in the quarries that supplied crushed rock for Camp Adair during WWII. The common rock is a pillow basalt with interstratified beds of tuff all dipping westward to northwestward. Zeolite minerals, volcanic glass, and palagonite are abundant along the edges of the pillows and in the volcanic breccia.

Late Cenozoic formations of the Willamette Valley are composed of alluvium deposited during various stages of alluviation by the Willamette River and tributaries (Baldwin, 1976). As a result, the Willamette and its larger tributaries have broad flood plains and meander belts.

According to Lawrence, Rosenfeld, and Ruddiman (1979), the major geologic structure of the area is the Corvallis fault which trends N50°E for about 56 kilometers from within the Coast Range to north of Corvallis, significantly oblique to the north-south trend of the Coast Range. Demonstrable motion on this fault is up on the west with at least 1500 meters of vertical stratigraphic separation. The fault is steeply dipping, but the actual altitude has never been determined. The fault itself is a zone of steep shears up to 150 meters wide including blocks of sandstone and basalt.

Paleomagnetic studies indicate very substantial tectonic rotation of the Oregon Coast Range between 20 and 50 million years ago. Simpson and Cox (1977) determined a clockwise rotation of 65° to 75° $\pm$ 12° for various flows of the Siletz River volcanics and of 64° $\pm$ 16° for the Flournoy Formation. These rotations probably explain the oblique structural

grain of the Coast Range (Lawrence, et al, 1979). The northwest trend of the Corvallis and other faults reflects clockwise rotation of these features since they were formed. The 20° difference in general trend between the Corvallis fault and the Kings Valley fault further west reflects the greater age of the Corvallis fault and therefore its greater rotation. According to Lawrence, et al (1979), studies of joint and fault patterns recorded as lineaments on U-2 high altitude flight, false-color infrared photography and SLAR imagery reveal major NE and NW sets of features. Thus study of these structural features offers an additional means of investigating the history of tectonic rotation of this area. The current north-south trending mountain range is a young, post Miocene feature developed across an older structural grain (Lawrence, et al, 1979).

Figure 6.2 (next page) is a generalized geologic map of the test area compiled from Vokes, et al (1954), Frank 1974), and Baldwin (1976). The three geologic units mapped are differentiated as follows: Qal is Quaternary alluvial deposits which includes unconsolidated sand, gravel, and silt. Ts represents Eocene sedimentary rocks consisting of tuffaceous and micaceous sandstone and siltstone, and includes the Tyee and Spencer formations. Tv represents Eocene volcanic rocks, mainly submarine pillow basalt, and includes the Siletz River series.

Hydrology

The fate of the approximately 100 cm of precipitation that falls in the test area annually is as one would expect - most of it evaporates, some is transpired to the atmosphere by vegetation, some runs off, and some infiltrates into the ground. Part of the water that infiltrates is retained as soil moisture; the remainder percolates downward to the zone of saturation where it is stored in aquifers and moves down gradient by the force of gravity to points of discharge, such as springs, seeps along stream channels, or wells (Frank, 1974).

According to Frank (1974), the alluvial fill of the valley is the principal aquifer and generally yields large quantities of water to wells. The Eocene sedimentary and igneous rocks of the eastern portion of the test area also yield water to wells but only in small to moderate quantities. All aquifers in the area are affected by seasonal changes in ground-water storage as the water table declines from a high position in winter to a low point in late summer (Frank, 1974).

Frank (1974) estimates that of the total amount of ground-water withdrawn during 1971 in the Corvallis-Albany area, 75% was for irrigation; 16% for industrial use; 7% for domestic use; and the remaining 2% for public use. It is highly probable that these figures are comparable for the test area as a whole.

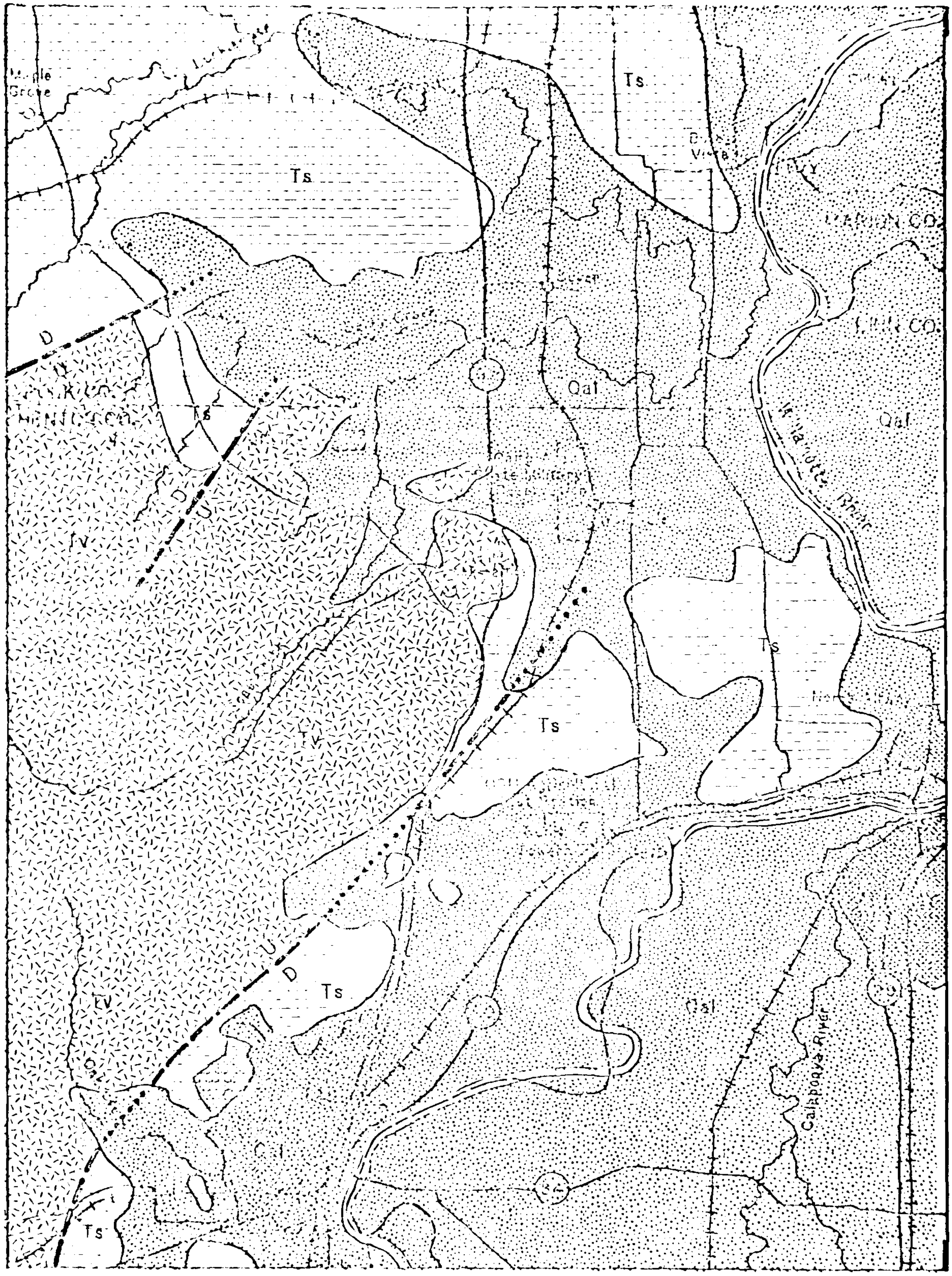

Figure 6.2: Generalized Geology
(see text for explanation, page 60)

Drainage in the Willamette Valley is toward the north along the Willamette River. Numerous smaller streams, both eastward from the Coast Range and westward from the Cascade Range, feed the Willamette. In the test area several small streams criss-cross the area and drain into the Willamette. These include the Luckiamute River, Berry Creek, Soap Creek, Oak Creek, and the Calapooya River.

Climate

Most of western Oregon has a maritime climate characterized by:

1. Mild temperatures with prolonged cloudy periods, muted extremes, and narrow diurnal fluctuations

2. Wet, mild winters and cool, relatively dry summers

3. Heavy precipitation (80 to 120 cm) with 75-85% occurring between October 1 and March 31, mostly as rain (Franklin and Dyrness, 1973).

Precipitation is generally cyclonic, the result of low-pressure systems approaching from the Pacific on the dominant westerlies. During the summer, storm tracks are shifted northward and high pressure systems bring extended periods of fair, dry weather (Franklin and Dyrness, 1973).

The drier and less muted climate of the Willamette valley is due to the rainshadow effect caused by the Coast Ranges to the west. After crossing the mountains the marine air is significantly cooler in winter, warmer in summer, and drier in all seasons than when it arrives at the coast. To the east the Cascade Range blocks the direct flow of extremely hot or cold continental air into the Willamette Valley. However, more severe winter temperatures do result from occasional invasions of continental air through the Columbia River gorge and down the valley (Knezevich, 1975).

Within the test area most climatic differences are caused by differences in elevation. In and around Corvallis, the mean annual precipitation is roughly 100 cm on the valley floor, and 125 cm in the foothills of the Coast Range along the western border of the test area. Only 20% falls as snow. Measurable precipitation occurs on the average of 150 to 160 days per year. Heavy winter storms occasionally cause major floods along the bottom lands of tributary streams more so than along the main stem of the Willamette River. Flooded pasture and only limited erosion result (Knezevich, 1975).

The mean temperature on the valley floor ranges from $0^{o}C$ in January to $28^{o}C$ in July, with only slightly cooler temperatures in the more elevated portions of the test area. For the month of August, the average daily minimum is $10^{o}C$ and the average daily maximum is $27^{o}C$ (Knezevich, 1975).

Soils

General characteristics of soils developed in the Willamette Valley and from Coast Range formations are described by Franklin and Dyrness (1973, pp. 12-16):

> "Soils on the valley floor, derived from silty alluvial and lacustrine deposits, were formed under dominantly grassland vegetation. Soil morphology largely reflects effects of landform position and soil drainage. Well-drained soils situated on the Willamette River flood plain are deep, moderately dark-colored and range from sandy loam to silty clay loam in texture, with the fine-textured soils occupying the highest positions. These soils generally lack subsurface horizons of clay accumulation. Soils occupying terrace positions generally exhibit a greater degree of profile development, typically having silt loam surface horizons underlain by silty clay loam subsurface horizons".

> "Soils derived from igneous and sedimentary rocks situated along the edges of the valley and on low hills are similar to those found in the adjacent Coast Ranges and Western Cascades Provinces. A typical, well-drained soil derived from basalt colluvium possesses a reddish-brown silty clay loam surface and a clay-textured subsurface horizon, with depth to bedrock averaging 1.5 meters".

> "Soils developing in the very extensive deposits of sandstone exhibit a wide range of characteristics despite the fact most are classified as Haplumbrepts (Western Brown Forest soils). On steep, smooth mountain slopes they tend to be shallow, stony loam textured, and brown or yellowish-brown in color. Deeper soils derived from sandstone colluvium occupy uneven, benchy slopes that generally exhibit some degree of continuing instability. Sandstone soils which show maximum profile development and are low in bases are classed as Haplohumults (Reddish Brown Lateritic soils)".

> "Soils developed from siltsone or shale parent materials resemble those derived from sandstone in some respects, but generally they are noticeably finer textured. Typically, they have a silt loam surface horizon and a silty clay or clay-textured B horizon. Those with thick, dark-colored A horizons are generally classed as Haplumbrepts, whereas soils with light-colored surface horizons have been classified as Dystrochrepts (Soils Bruns Acides)".

"Over most of the Coast Ranges Province, soils derived from basalt are Haplumbrepts. Deep, well-developed profiles are reddish-brown in color and are relatively stone free. Surface textures are generally clay loam and the subsoil, a silty clay loam. Most often, however, basaltic soils tend to be fairly shallow and stony. Some Haplohumults on basalt parent materials are found in the southern portion of the province".

Because the formation of soil is influenced by many factors, the potential for tremendous variety exists. The major factors are geology (or parent material), physiography, climate, vegetaton, biological forces, and time. When different factors or combinations are dominant, different soils result.

Within the test area several different soils are differentiated on the basis of textural and compositional features. However, they are grouped into three types based on the dominant factor - physiography. The three types are: (1) soils of the bottom lands, (2) soils of the Willamette Valley alluvial terraces, and (3) soils of the foothills. Figure 6.3 is a Generalized Soils map of the test area based on data by Knezevich (1975) and on physiography. According to Knezevich (1975), bottom land soils are deep, well to poorly-drained silty clay loams and fine sandy loams. Alluvial terrace soils are deep, well to poorly drained silt loams and silty clay loams. Soils of the foothills are shallow, well to somewhat poorly drained silty clays to silt loams.

An aspect of soils important to this study is moisture content. Soil moisture content at a given location varies with soil type, vegetation cover, time of day, time of year, climatic conditions, and numerous other more minor factors. Table A.2 lists the soil moisture content, sample location numbers, and collection times for the soils sampled during ground data collection in the test area. It can be seen that moisture content generally ranged from 2% to 7% at the time of collection. However, where an area was recently irrigated soil moisture content was as high as 20% to 25%.

Land Use

Land use and land cover information was compiled by the United States Geological Survey from source materials dated 1974-1975. Verification was made by field checking, also by the U.S.G.S. Figure 6.4 (next page) is a generalized Land Use map of the test area. The land use categories are defined below:

C - Cropland and Pasture
O - Orchards, Groves, Vineyards, and Horticultural Areas
A - Other Agricultural Land

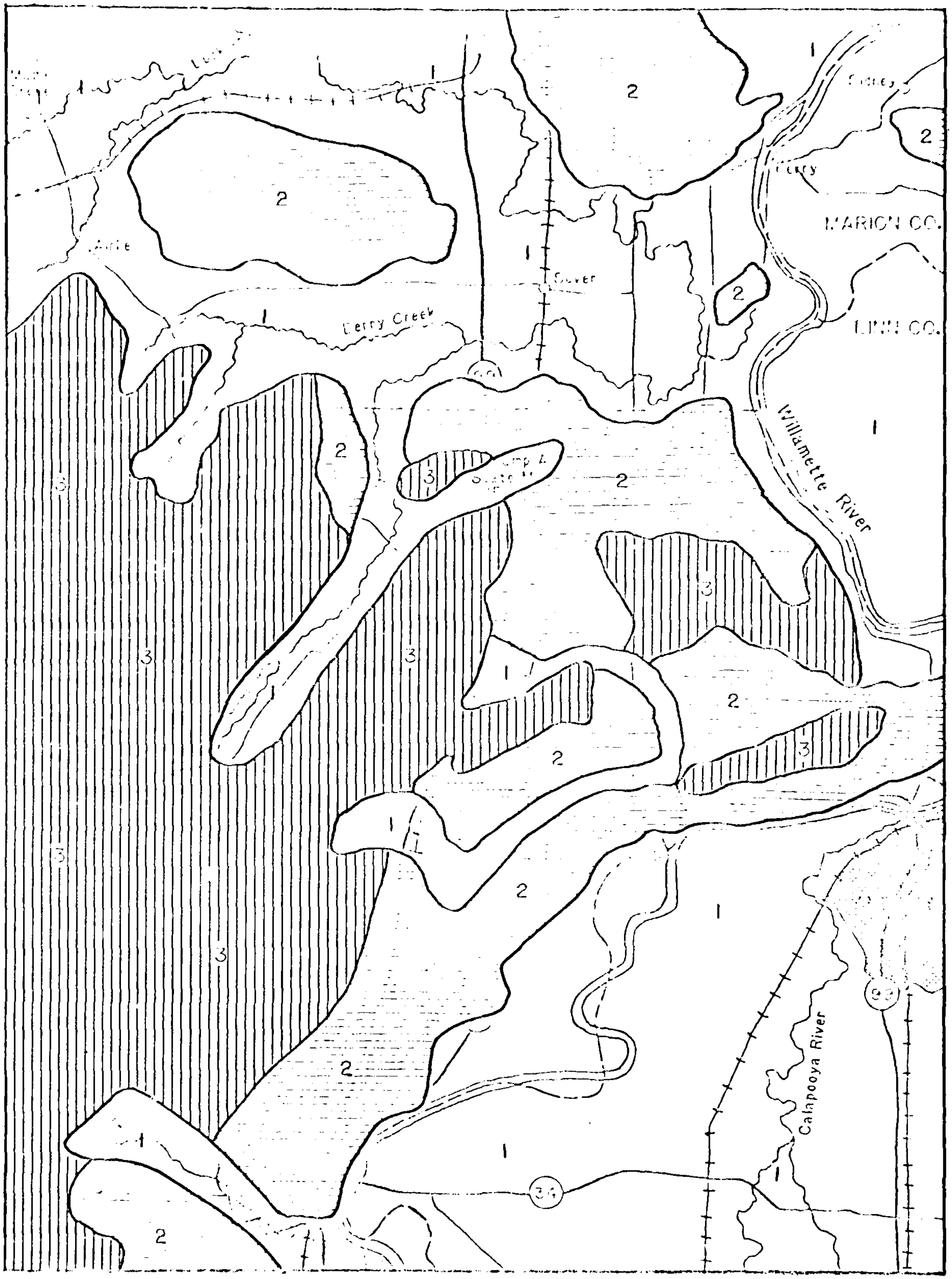

Figure 6.3 : Generalized Soils Map
(see text for explanation, page 64)

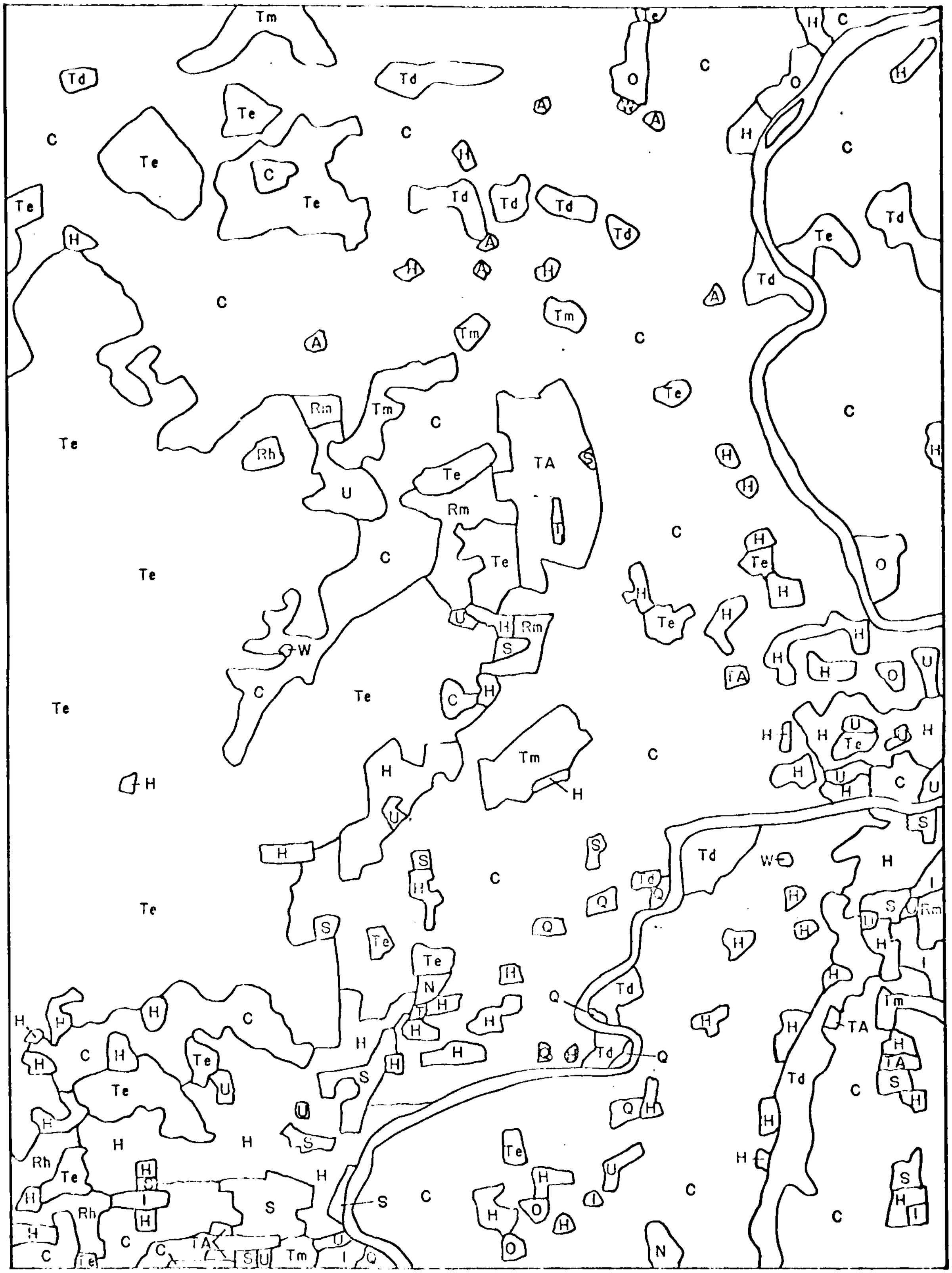

Figure 6.4: Land Use Map
(see text for explanation, page 64-67)

H - Residential
S - Commercial and Services
I - Industrial
T - Transportation, Communications, and Utilities
U - Other Urban Land
Rl- Herbaceous Rangeland
Rm- Mixed Rangeland
Td- Deciduous Forest Land
Te- Evergreen Forest Land
Tm- Mixed Forest Land
N - Nonforested Wetland
Q - Quarries, Strip Mines, and Gravel Pits
TA- Transitional Areas
W - Water Body

The land use map is intended as a general guide to the land use and land cover of the test area. Much greater detail could be obtained at the scale of aerial photographs, however, this map can be a useful reference when analyzing and interpreting the various types of imagery included in this reference image set. Furthermore, this 1974-1975 classification can be compared with the land use classification produced from Landsat data utilizing the IDIMS system and presented earlier in this report.

Cultural Features

A large variety of cultural features are present within the test area. The dominant feature is agriculture. Most of the area of the Willamette Valley is occupied by croplands and pasture, even part way into the foothills of the Coast Range. Logging within the foothills also seems to be a common activity as evidenced by the presence of logged areas and the number of logging trucks observed on the roads.

Two large urban areas are found within the test area, both along the Willamette River. On the western border of the Valley is Corvallis. Downstream and roughly 10 kilometers to the northeast is Albany. Both of these urban areas have populations on the order of 25,000. Several smaller towns and crossroad junctions dot the test area north of Corvallis and Albany. Numerous roads, railroads, and transmission lines criss-cross the test area and connect the towns and agricultural areas. Also, several major highways link Corvallis-Albany with other urban areas of Oregon.

Another cultural feature worthy of mention is Camp Adair State Military Reservation located roughly in the center of the test area. Camp Adair is a former U.S. Army base.

7 - CONCLUSIONS

1. The near-simultaneously collected imagery from the Corvallis, Oregon test area provides an excellent set of images for interpretation. The advantage of using simultaneously collected imagery from multiple sources is clearly evident from this study. Although each imagery has definite advantages in certain situations, the multi-source method allows the imagery types to compliment each other. Also, should one system fail or the collecting conditions preclude one type of imagery the other types can be utilized.

2. The availability of detailed ground truth information collected simultaneously with imagery collection and details of sensor specifications, flight times, dates, etc. proved to be of great value for interpretation of the images, correlation between imagery types, and as calibration data for Landsat multispectral classification of land types.

3. The data collected for the Fulda Gap look-alike area and the subsequent interpretation provides an excellent set of reference imagery for this physiographically significant site.

4. Stereoscopic coverage is of great value during interpretation because the vertical exaggeration on the apparent three-dimensional image allows recognition of relief and other terrain parameters.

5. Multiple look-directions for radar imagery also proved to be an important feature. Detail hidden within a radar shadow can be detected from a different look-direction. Also, features viewed at various range directions result in additional useful information.

6. The digital data of Landsat and the multispectral classification constructed from it on the IDIMS computer system provides an excellent source of terrain analysis information. This is especially true when the information is used in conjunction with the other imagery types and the ground truth information.

7. Differentiation between various agricultural fields, between asphalt and dirt roads, and between various building materials is possible because of the characteristics of these features on the different imagery types. When two features give similar spectral responses on one imagery type, they can usually be distinguished on another type.

8. Differentiation of the numerous types of vegetation, expecially detailed crop identification, requires a more complex evaluation of the vegetation-sensor interaction and is beyond the scope of this study.

APPENDIX

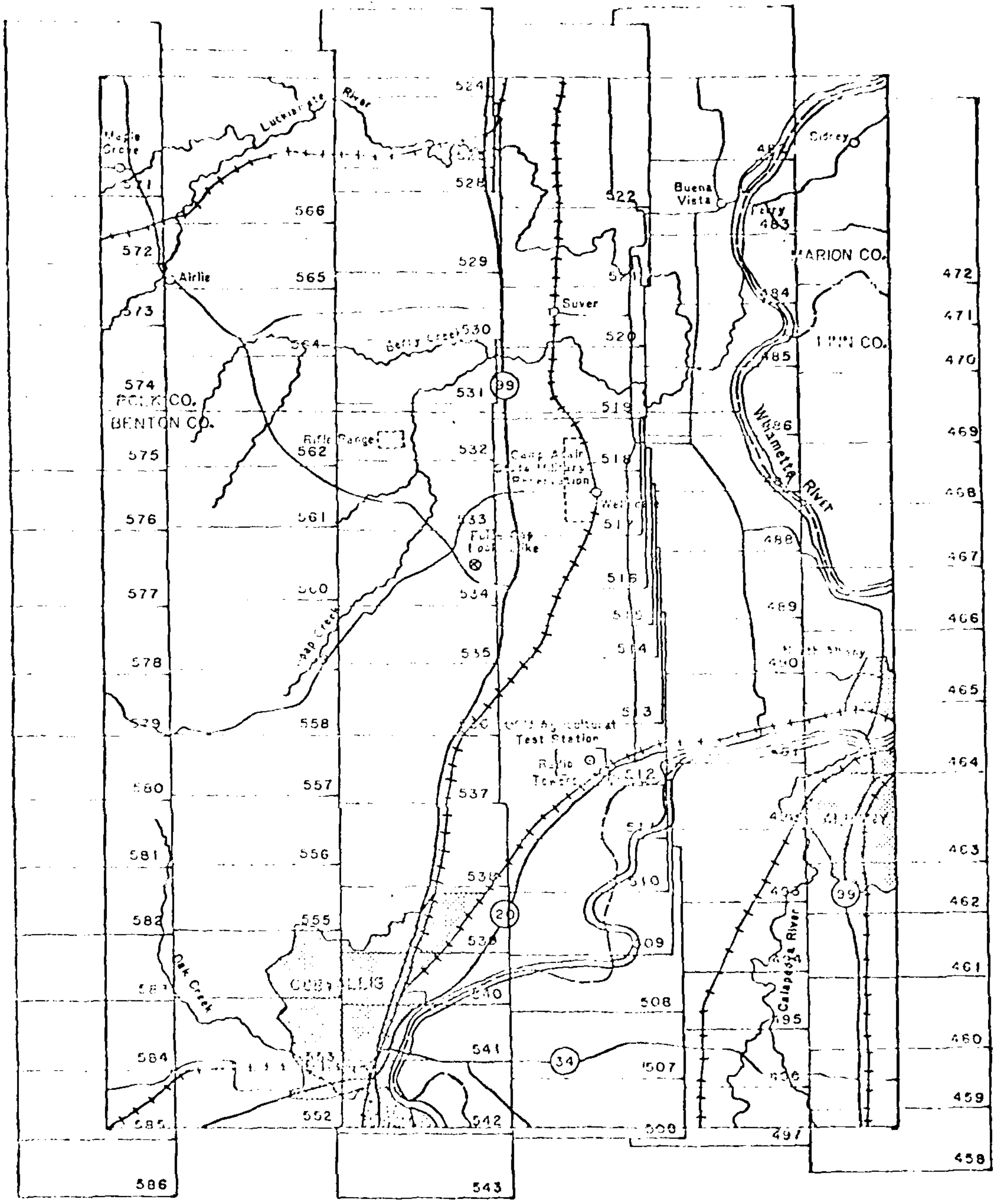

Figure A.1: Panchromatic Index

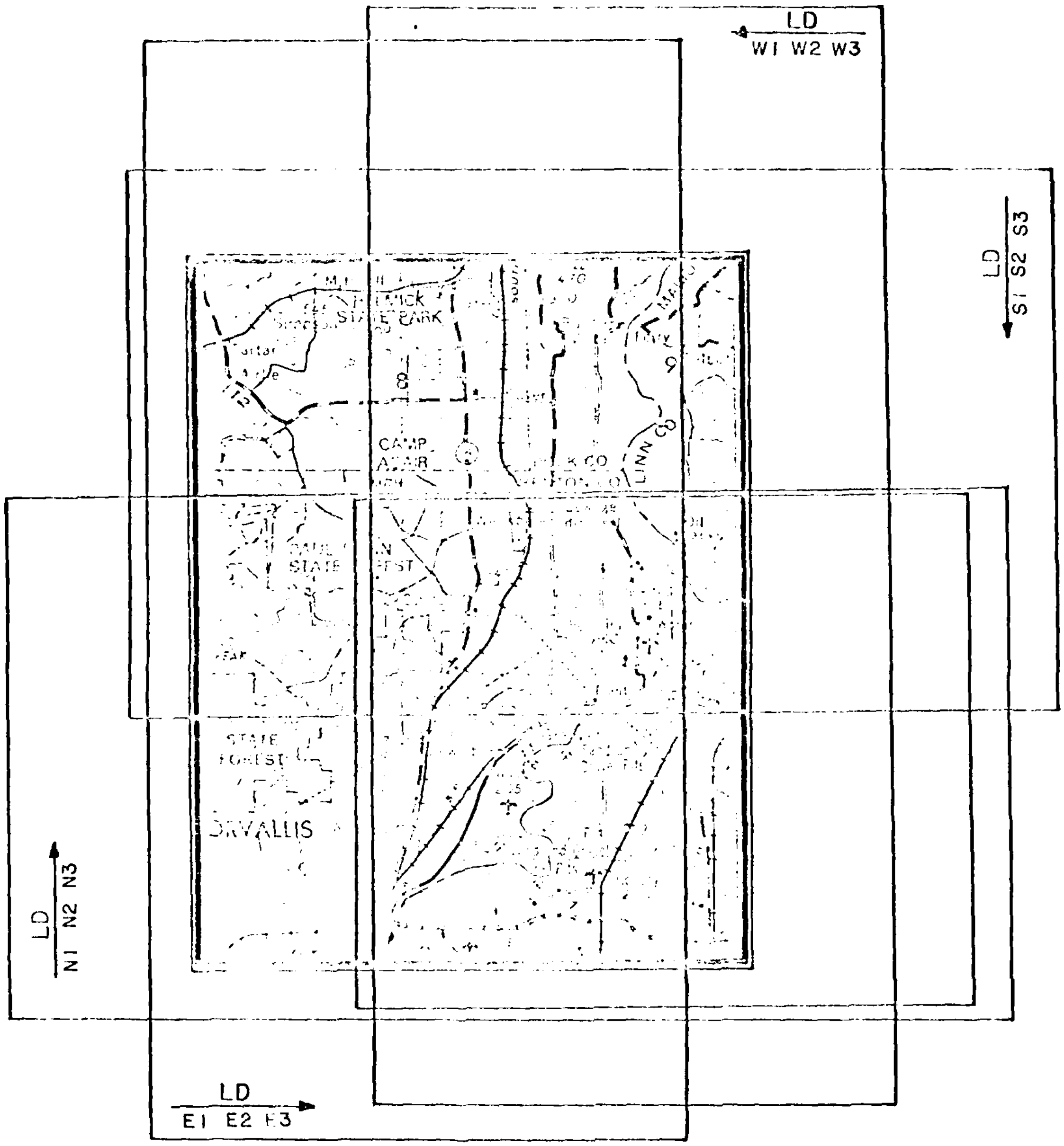

Figure A.2 : Radar Coverage Index

LD is look-direction. N,S,E, and W signify the compass direction. The numbers represent the three collection dates : 1 is 13 August, 2 is 14 August, and 3 is 19 August.

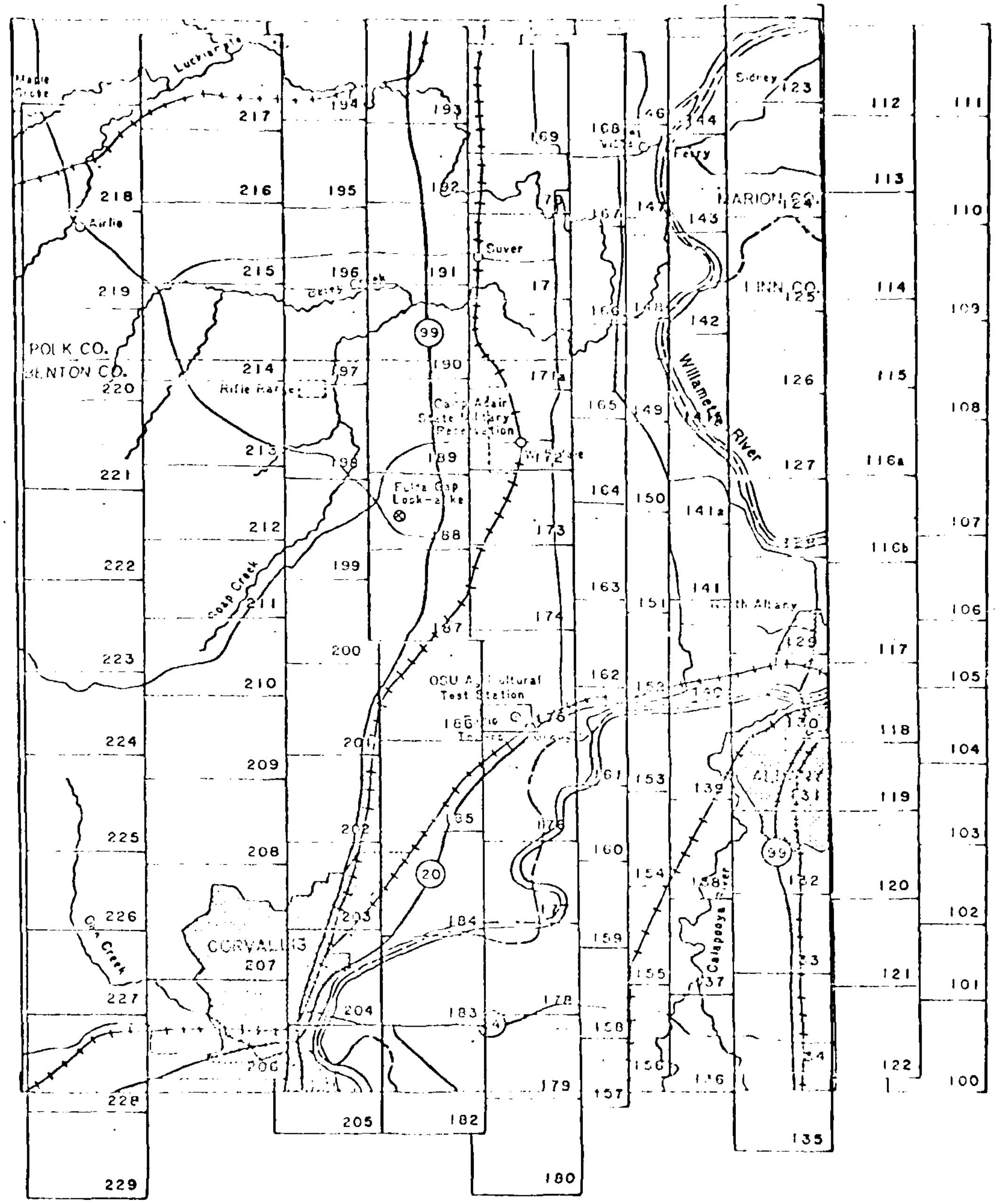

Figure A.3: Thermal Infrared Index

TRAVERSE 1

Coll Site	Coll Time	Air temperature	Radiant temperatures: Asphalt road	Gravel road	Road shoulder	Vegetation
1-1	0400	12.0°C	12.0°C			12.2°C
1-2	0410	12.2	12.1		11.8°C	-
1-3	0419	12.8	12.5			10.8
1-4	0426	12.5	14.0			13.5
1-5	0434	12.1	14.2			11.8
1-6	0441	13.8	15.0			-
1-7	0448	13.0	13.0			11.5
1-8	0455	12.8	13.0			11.5
1-9	0501	12.0	15.0			10.0
1-10	0504	13.0	14.0			12.5
1-11	0510	14.0	14.0			13.5
1-12	0520	-	-		14.5	13.5
1-13	0533	13.7	17.5			15.0
1-14	0540	13.7	16.0			13.5
1-15	0546	14.0	14.7			13.2
1-16	0553	14.5	15.5			14.5
1-17	0559	15.0	16.0			13.5
1-18	0607	14.5	17.5			-

TRAVERSE 2

Coll Site	Coll Time	Air Temperature	Radiant Temperatures: Asphalt Road	Gravel Road	Rd. Shoulder	Water	Metal Mine	Plastic Mine
2-1	0408	14.0°C	16.5°C		14.0			
2-2	417	15.0	17.0		15.0			
2-3	430	-	17.0		14.0			
2-4	436	-	14.5		13.0			
2-5	441	15.0	16.0		15.5			
2-6	447	14.5	15.0		14.0			
2-7	452	14.0	17.0		16.0			
2-8	458	14.0	16.0		15.0			
2-9	506	14.0	16.0		15.0			
2-10	512	14.0	17.0		15.0			
2-11	517	15.0	18.0		17.0			
2-12	525	14.5	20.0		17.0			
2-13	531	13.5	18.0		14.0			
2-14	535	15.0	-	19.0	15.0			
2-15	542	14.5	-	17.0	14.0			
2-16	549	15.5	19.0		14.0			
2-17	554	13.5	-	14.0	14.0			
2-18	602	14.0	-	14.0		14.0		
2-19	619	15.0	-	19.0				
2-20	625	14.5	20.0	18.0				
2-21	628	17.0	-	18.0				
2-22	-	14.0	-		15.0		13.0	12.0

TRAVERSE 3

Coll Site	Coll Time	Air Temperature	Soil Temp.	Water	No radiant temperatures measured
3-1	0405	12.5			
3-2	0413	13.5	18.0		
3-3	0418	13.5			
3-4	0422	14.0			
3-5	0426	14.0	16.0		
3-6	432	15.0			
3-7	435	14.5			
3-8	440	14.5	18.0		
3-9	447	15.0			
3-10	456	15.0			
3-11	500	15.5	17.0		
3-12	508	14.5			
3-13	524	15.5	18.0		
3-14	531	17.0			
3-15	535	15.0		18.0	

Table A.1 : Temperature Data

TRAVERSE 1

Sample	Collection Time	Percent Moisture
1-1	0400	4.7%
1-2	410	4.9
1-3	419	8.2
1-4	426	2.4
1-5	434	2.0
1-6	441	No sample
1-7	448	2.2
1-8	455	4.3
1-9	501	2.1
1-10	504	3.9
1-11	510	1.7
1-12a	520	3.1
1-12b	520	9.4
1-12c	520	24.2
1-13	533	1.6
1-14	540	2.5
1-15	546	2.0
1-16	553	4.2
1-17	559	10.2

TRAVERSE 2

Sample	Collection Time	Percent Moisture
2-1	0408	4.2%
2-2	417	3.5
2-3	430	20.4
2-4	436	25.0
2-5	441	1.0
2-6	447	3.7
2-7	452	1.5
2-8	458	7.8
2-9	506	1.1
2-10	512	No sample
2-11	517	6.0
2-12	525	9.4
2-13	531	5.4
2-14	535	7.2
2-15	542	8.3
2-16	549	8.9
2-17	554	9.3
2-18	602	5.3
2-19	619	6.9
2-20	625	6.3
2-21	628	5.2
2-22	-	3.4

TRAVERSE 3

Sample	Collection Time	Percent Moisture
3-1	0405	5.8%
3-2	413	7.8
3-3	418	12.0
3-4	422	6.7
3-5	426	4.2
3-6	432	2.7
3-7	435	3.0
3-8	440	3.0
3-9	447	7.7
3-10	456	6.6
3-11	500	2.6
3-12	508	4.2
3-13	524	5.8
3-14	531	2.2
3-16	No samples	
3-17	taken due to	
3-18	ferry closure	

Table A.2 Soil Moisture Content
See Laboratory Procedures for description
of Soil Moisture Content Evaluation.

Date	Air Temperature		Measurable	Measurable
	Maximum	Minimum	Precipitation	Evaporation
August 11	33.3°C	8.9°C	0 cm	0.6 cm
August 12	26.7	8.3	0	0.6
August 13	26.7	11.7	0	0.5
August 14	26.1	7.8	0	0.5
August 15	25.0	6.7	0	0.6
August 16	23.9	10.5	0	0.5
August 17	26.1	9.4	0	0.5
August 18	26.1	8.3	0	0.5
August 19	23.3	6.7	Trace	0.3
August 20	28.3	7.8	0	0.5

Table A.3 Meteorological Data

Source: Hyslop Field Laboratory,
Oregon State University
Agricultural Test Station

Time	Air	Wind Speed - Direction		Relative
	Temp.	3m height	30m height	Humidity
300 hrs.	12.8°C	6 kph N	13 kph N	-
400	12.2	8	19	-
500	12.2	8	18	98%
600	13.9	10	21	97
700	14.4	10	19	97
800	14.4	11	22	95
900	15.0	10	21	78
1000	15.6	10	24	70
1100	16.1	10	21	62
1200	18.3	10	24	48
1300	20.0	8	16	36
1400	22.8	11	19	30
1500	26.7	11	19	22
1600	26.1	13	24	22
1700	24.1	12	22	24

Table A.4 Weather Conditions at time
of data collection - August 13

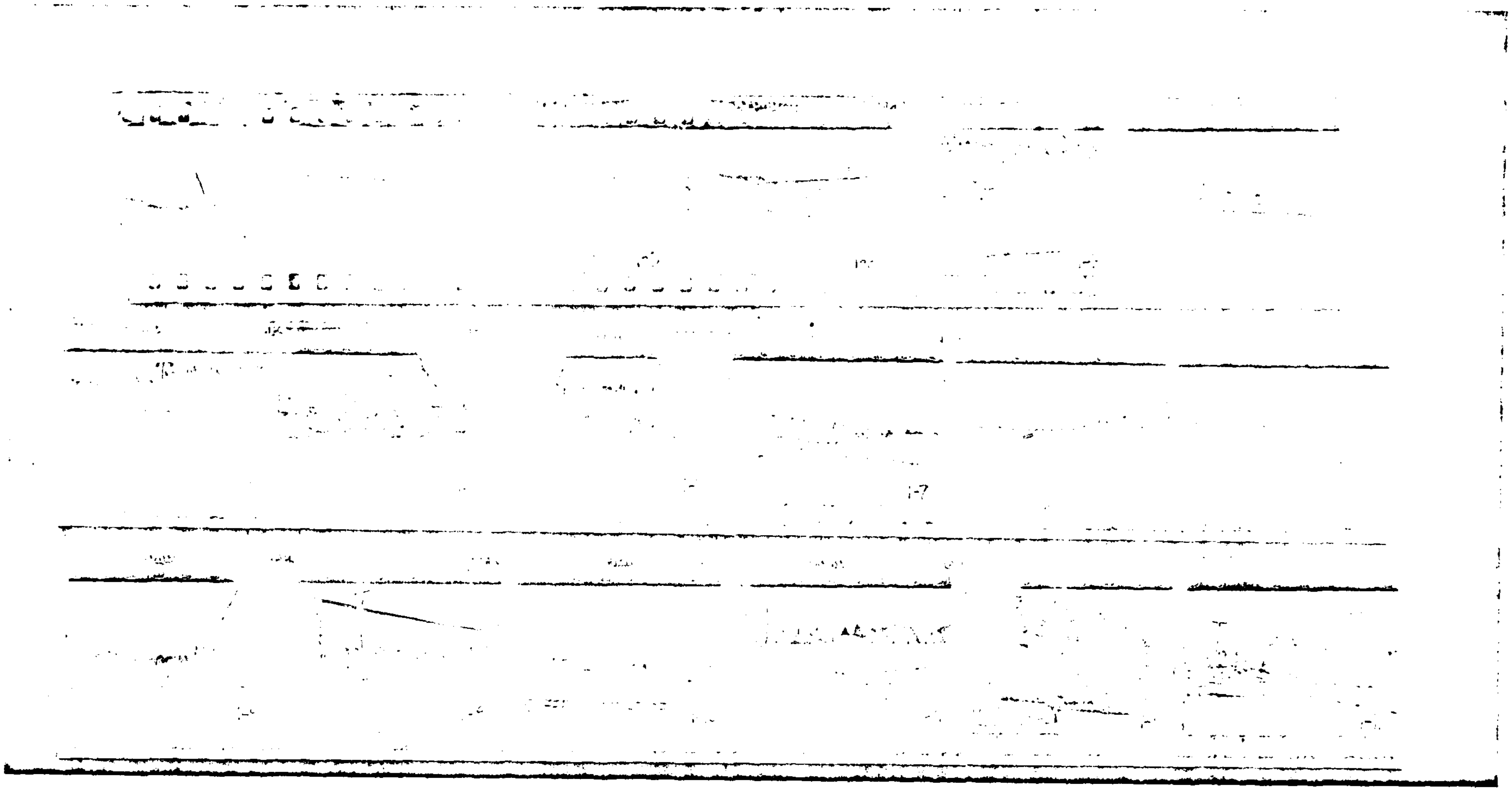

Figure A.4 : 35mm photographs of ground data collection sites - Traverse I

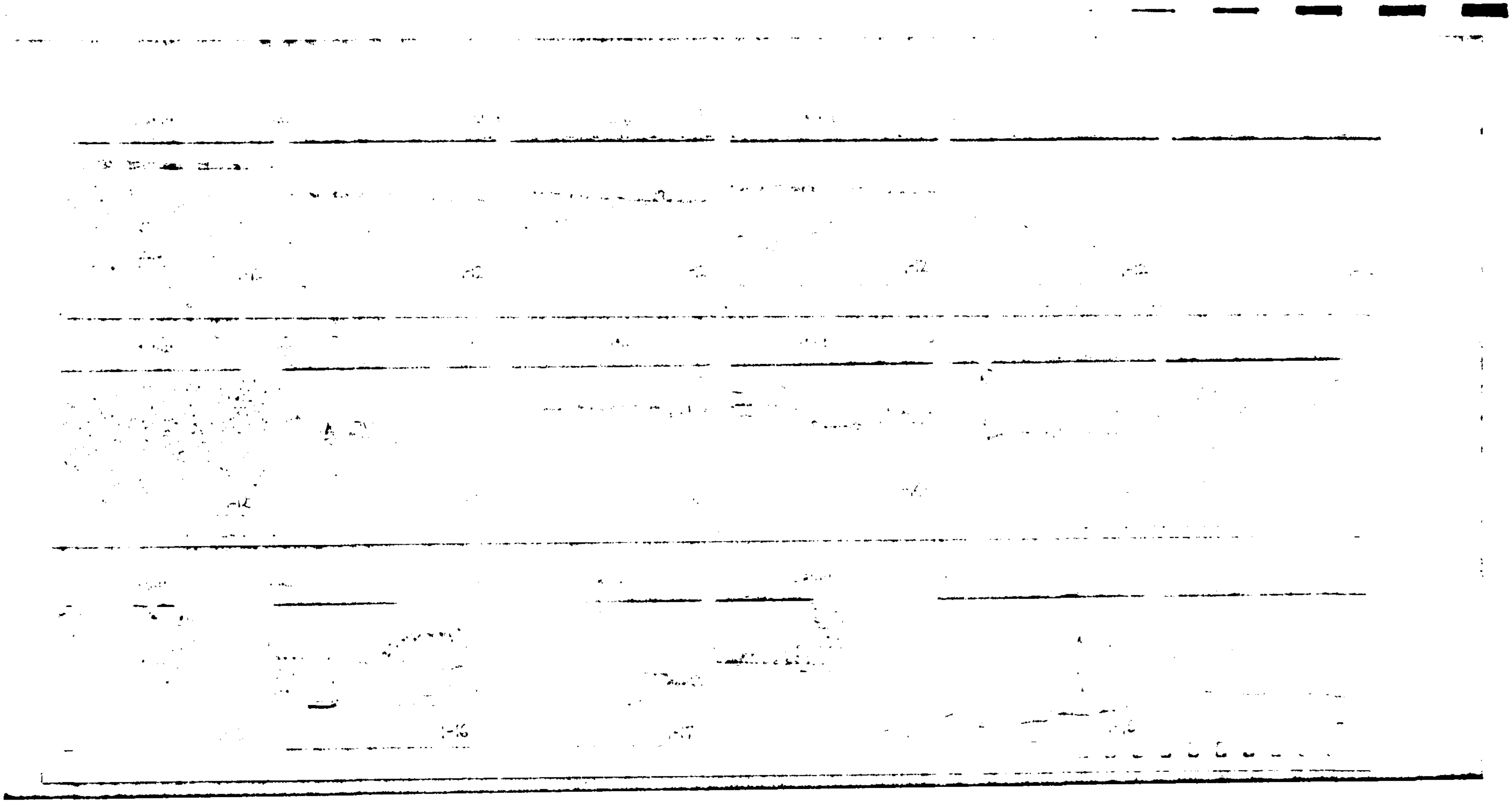

Figure A.4 : 35mm photographs of ground data collection sites - Traverse 1

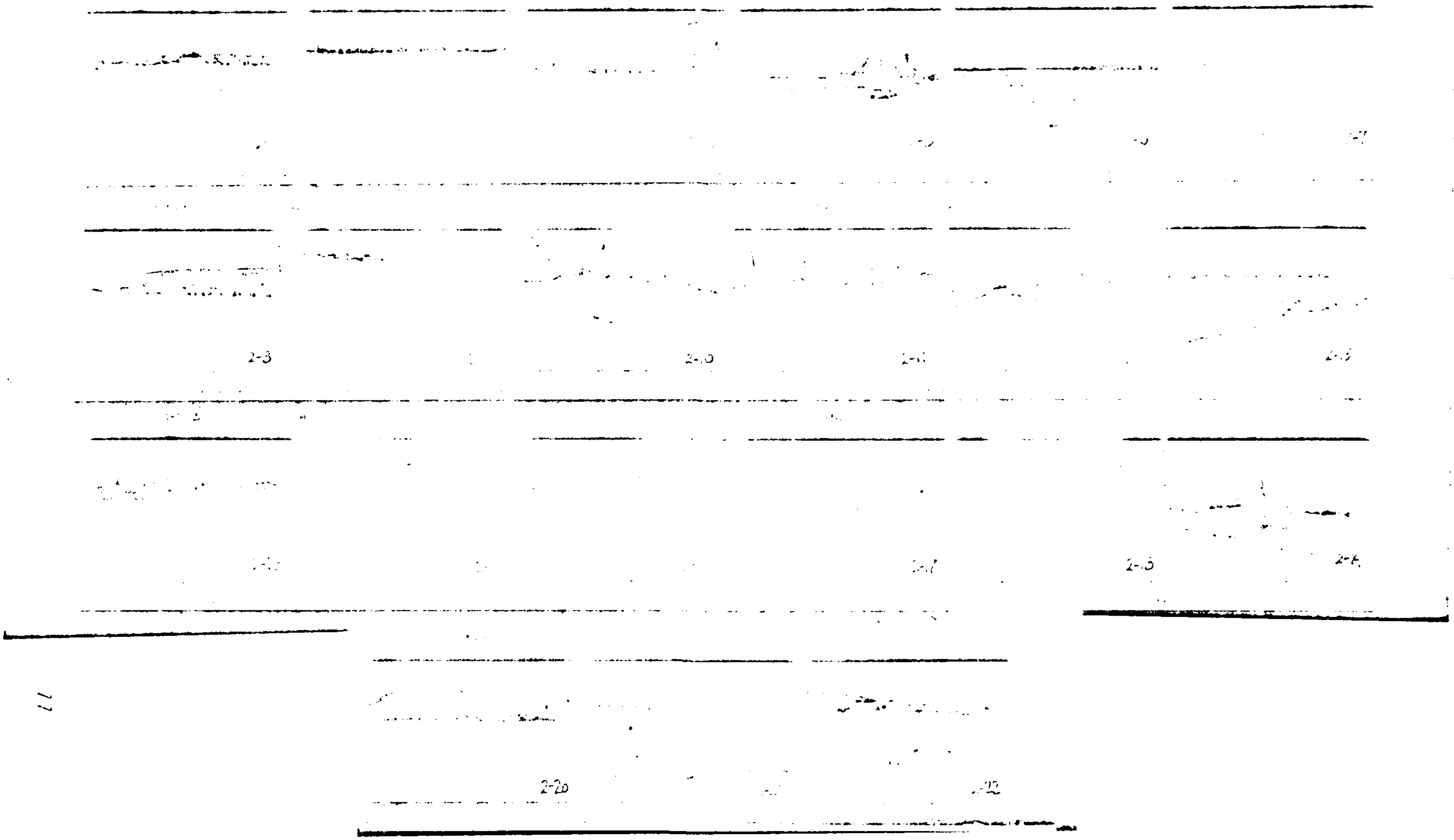

Figure A.4 : 35mm photographs of ground data collection sites - Traverse 2

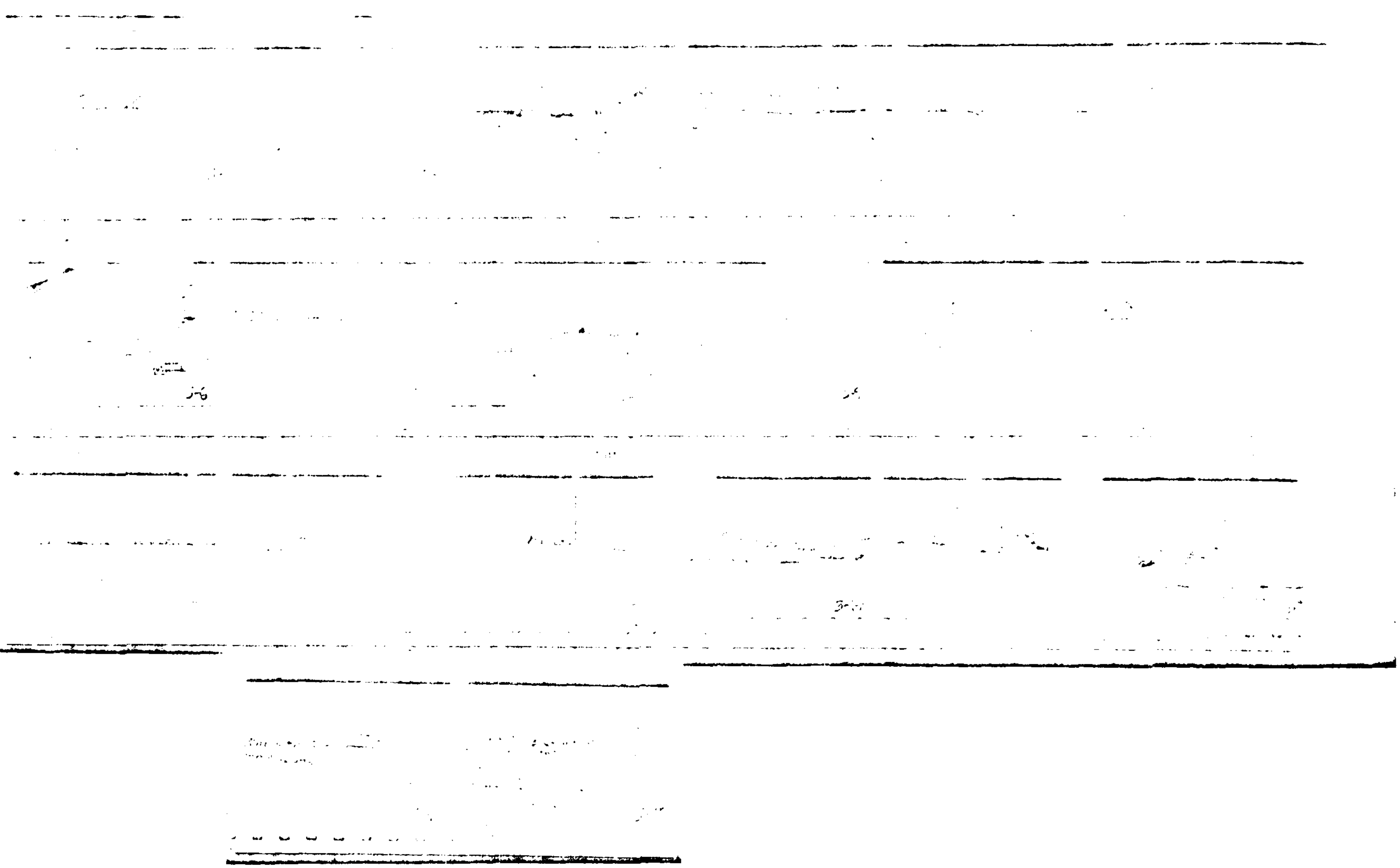

Figure A.4 : 35mm photographs of ground data collection sites - Traverse 3

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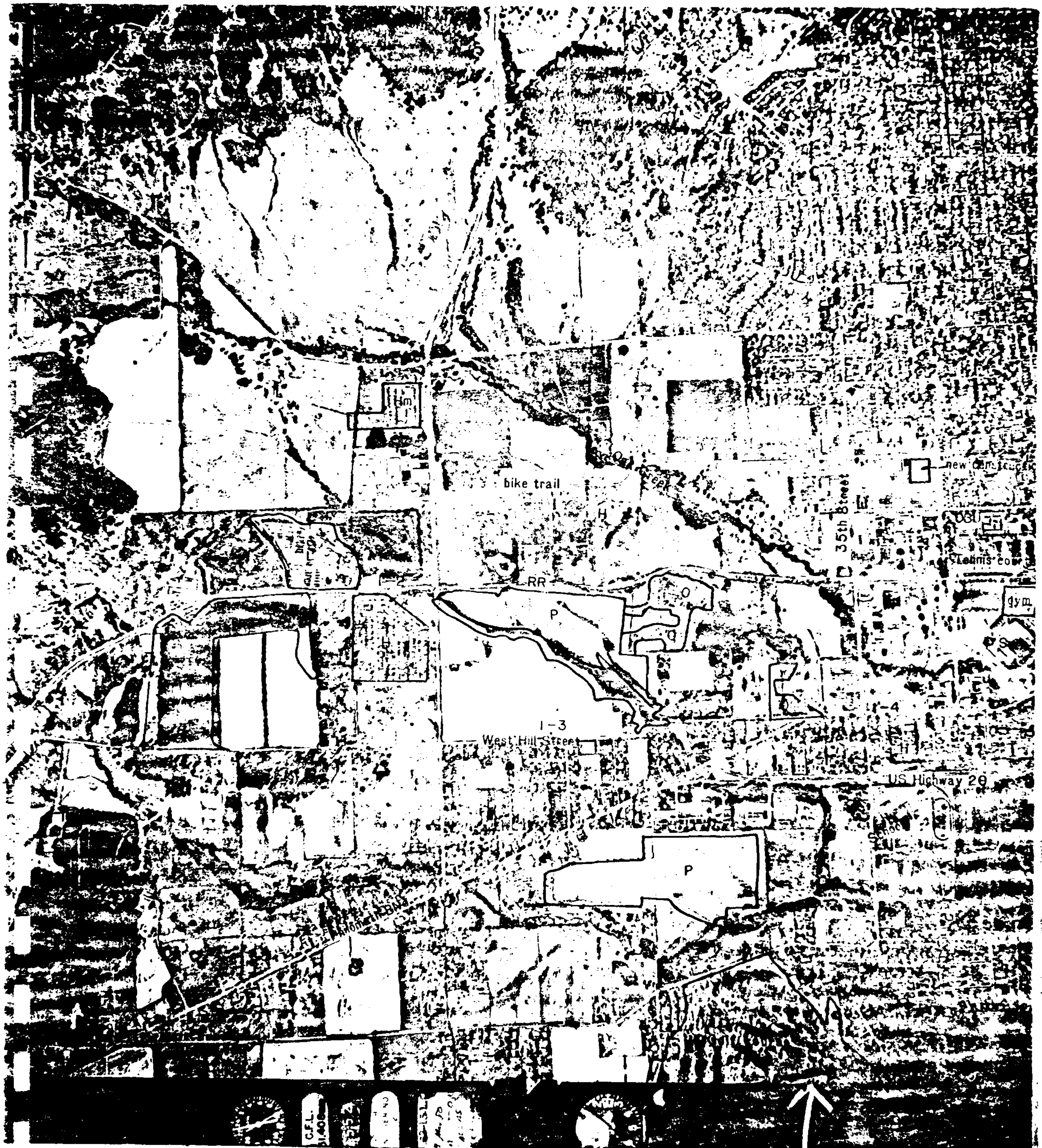


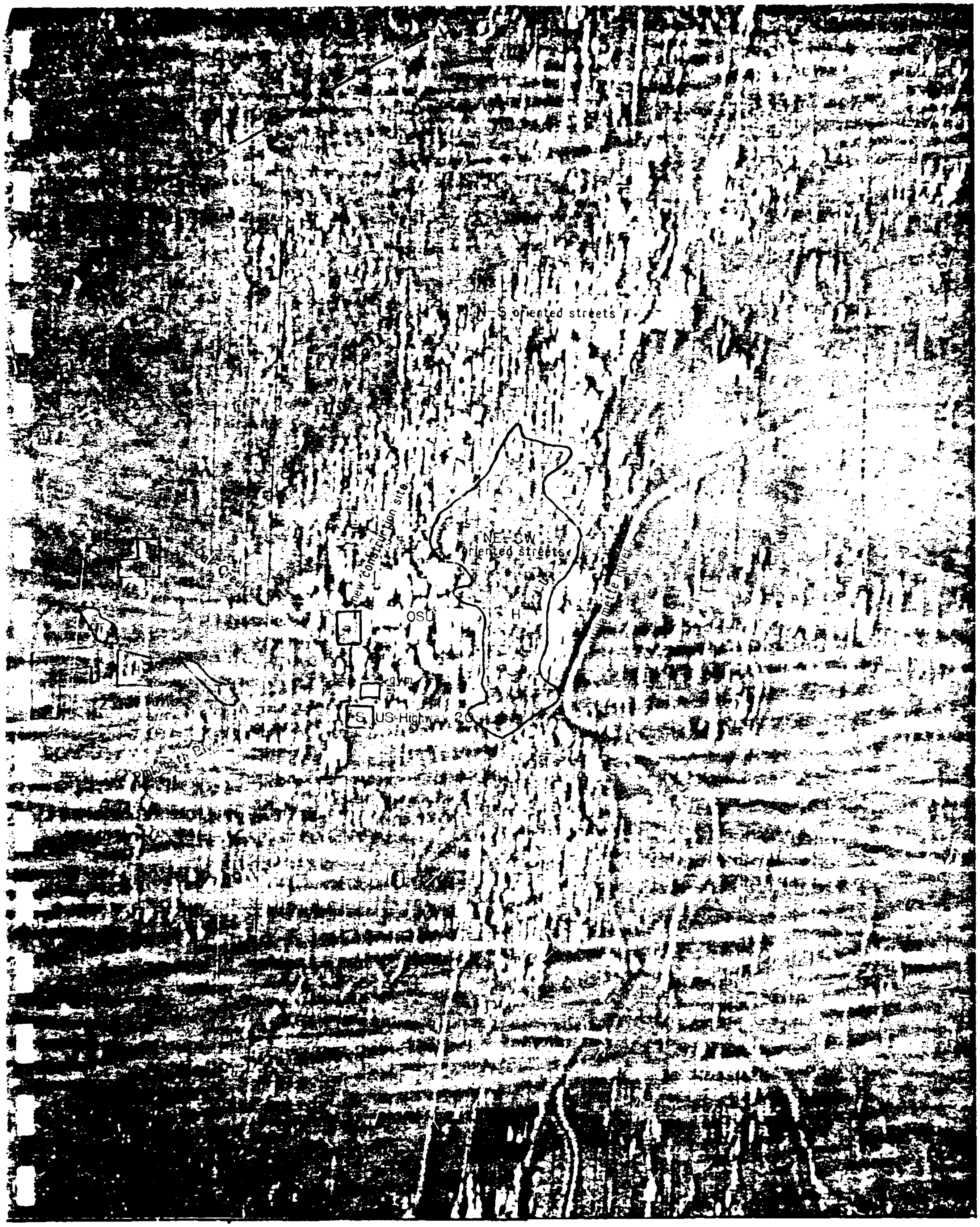
Corvallis, Oregon
Panchromatic
1 August 1980

Figure 2.1

N

Legend

RR	Railroad tracks	H	Residential area
S	Stadium	P	Bare ground
Pg	Parking area, gravel	Hm	Mobilehome Park
T	Trees	L	Lumber mill
		O	Orchard



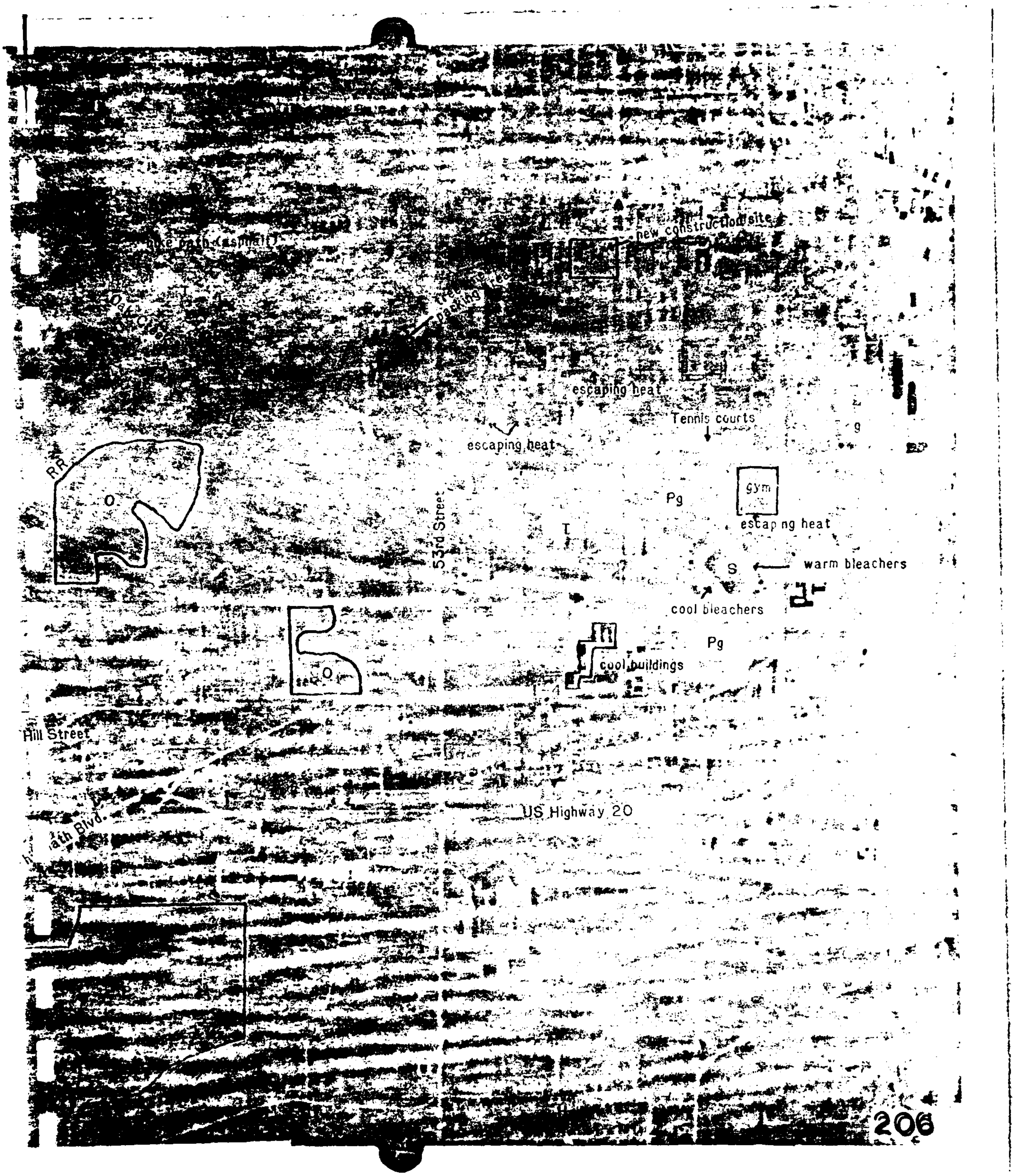
Legend

Corvallis, Oregon
X Band Radar Imagery
18 August 1980

Figure 2.3

N

LD	Look direction	Hm	Mobilehome Park
S	Stadium		
T	Trees		
H	Residential area		



C vallis, Oregon
Thermal Infrared
19 August 1980

Figure 2.4

N

Legend

RR	railroad tracks	O	Orchard
P.	bare ground	S	Stadium
H	Residential	T	Trees
g	grass	Pg	Parking area, gravel

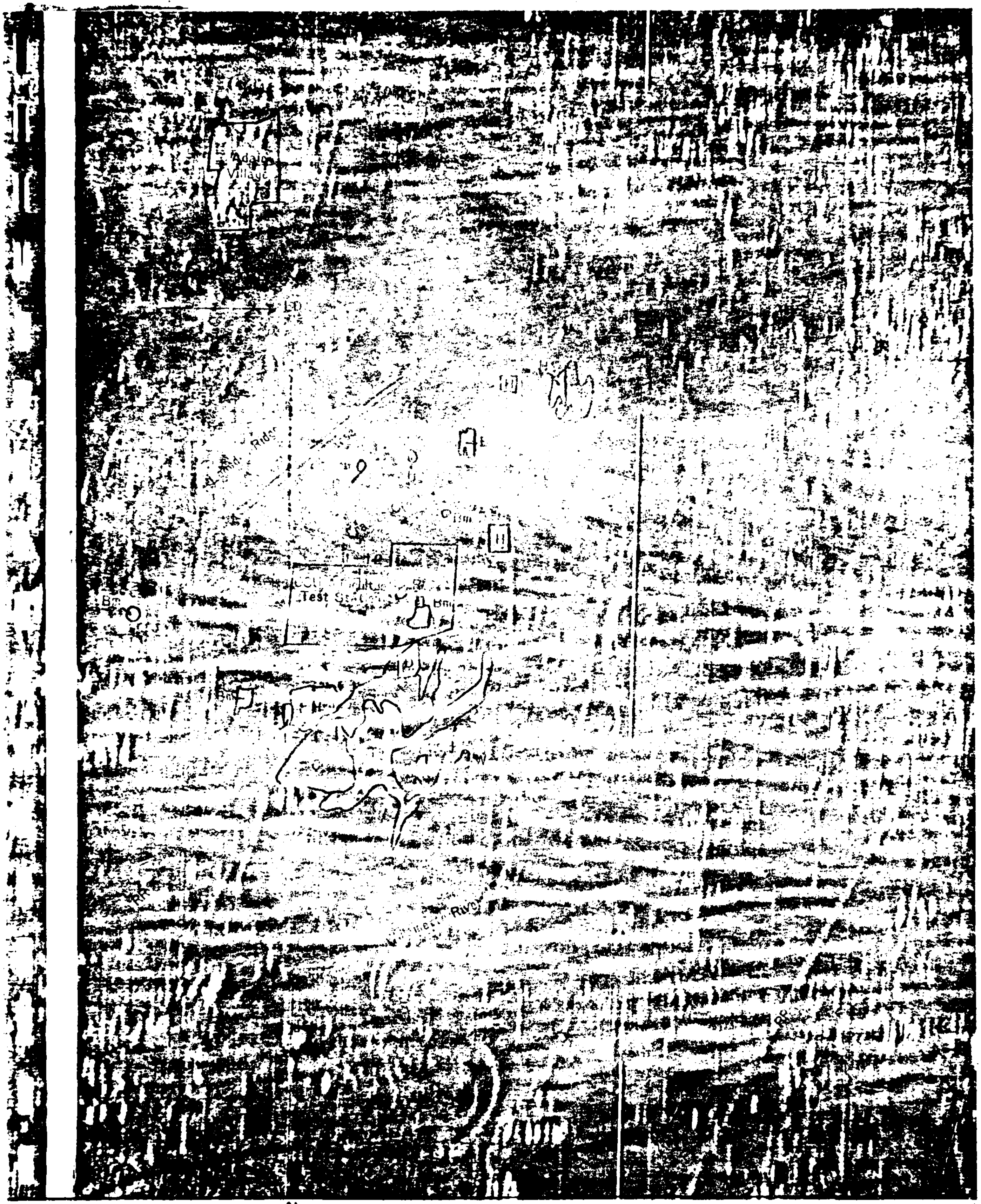
Panchromatic

19 August 1980

Figure 2.5

N

- Ch — Crops harvested
- g — Grasslands
- R — Radio towers
- Bm — Metal building
- H — Residential areas
- P — Bare ground
- O — Orchards
- D — Drive-ins
- W — Water body
- T — Trees



Granger, Oregon

X Band Radar

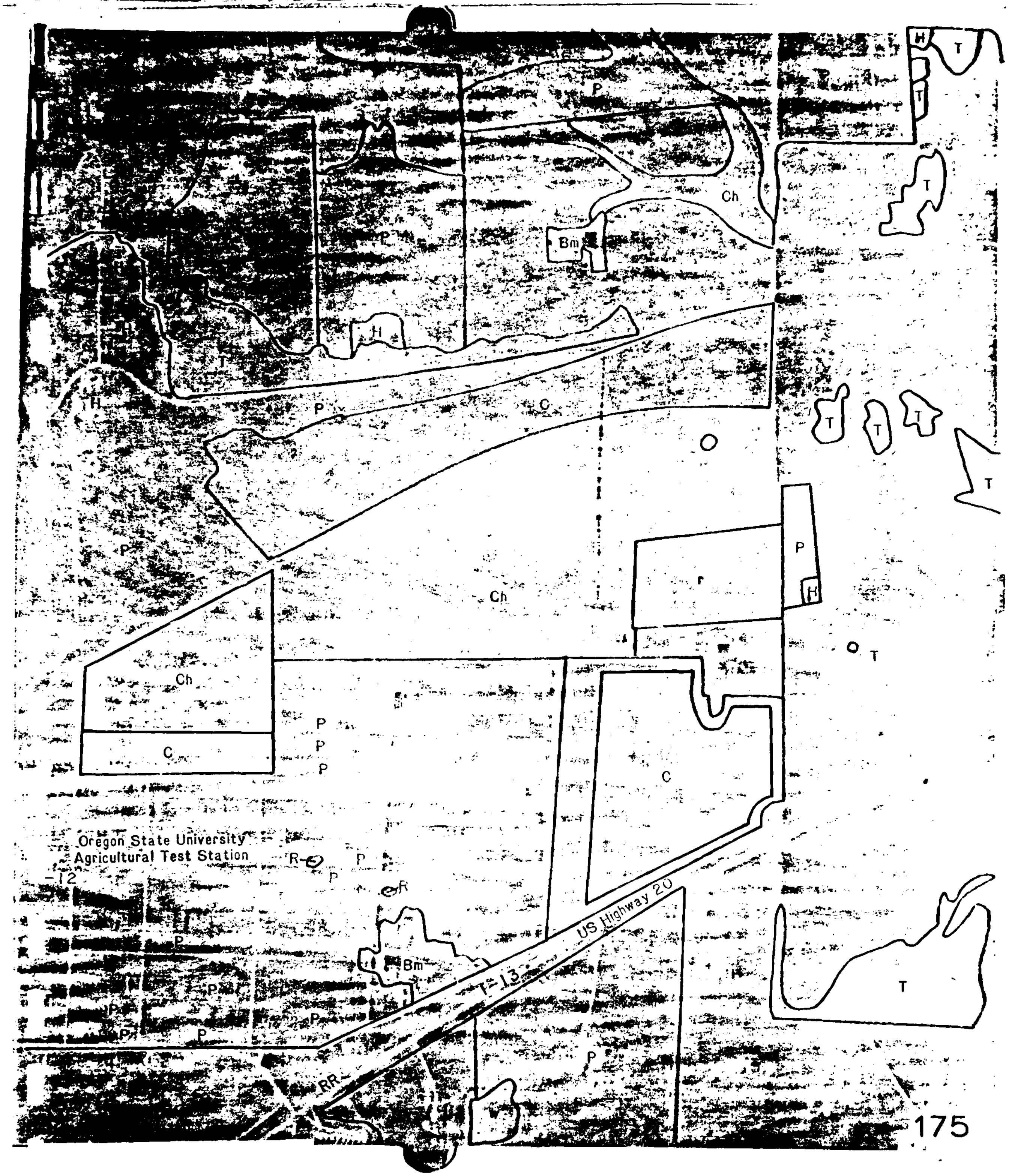
18 August 1980

Figure 2.7

N

Legend

C	Crops	T	Trees		
H	Residential area	W	Water body	LD	Look direction
Bm	Metal building	RR	Railroad		
R	Radio towers	D	Drive-In		



Granger, Oregon
Thermal Infrared
19 August 1980

Figure 2.8

N

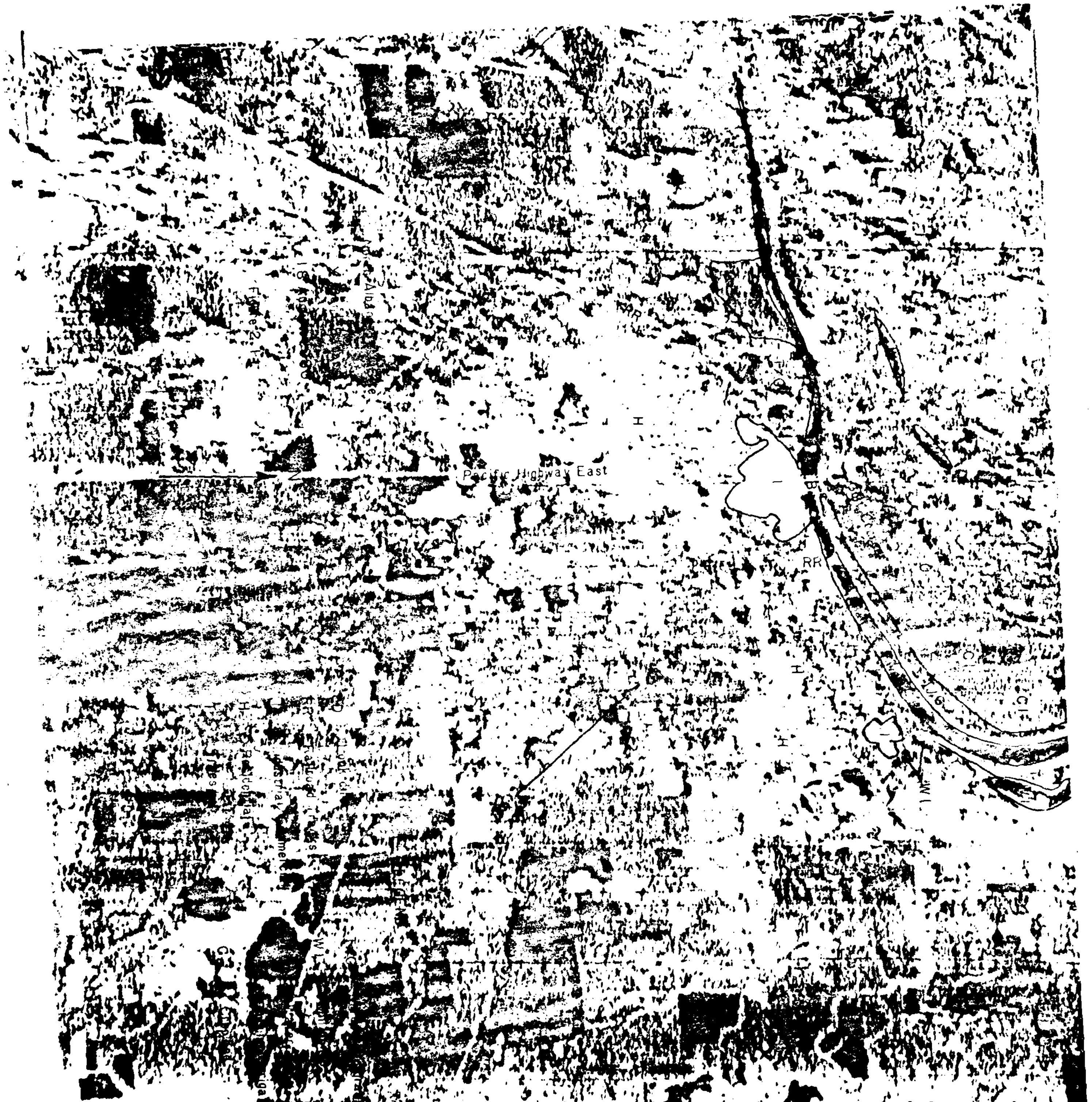
Legend

H	Residential area	C	Cropland
R	Radio towers	Ch	Crop harvested
RR	Railroad tracks	r	row crops
Bm	Metal building	w	water
T	Trees		
P	Bare ground		

August 1980

Figure 2.9

I	Commeria/Industrial	O	Orchard
C	Cropland	Hm	Mobile homes
B	Bridge	g	Grass
H	Residential	CI	Circular irrigation
T/G	Trees and grass mixed	RR	Railroad Tracks
T	Trees	Pa	Asphalt parking area
W	Water	WI	Mill ponds


Pacific Highway East
RR

North Albany Test Site

Thermal Infrared

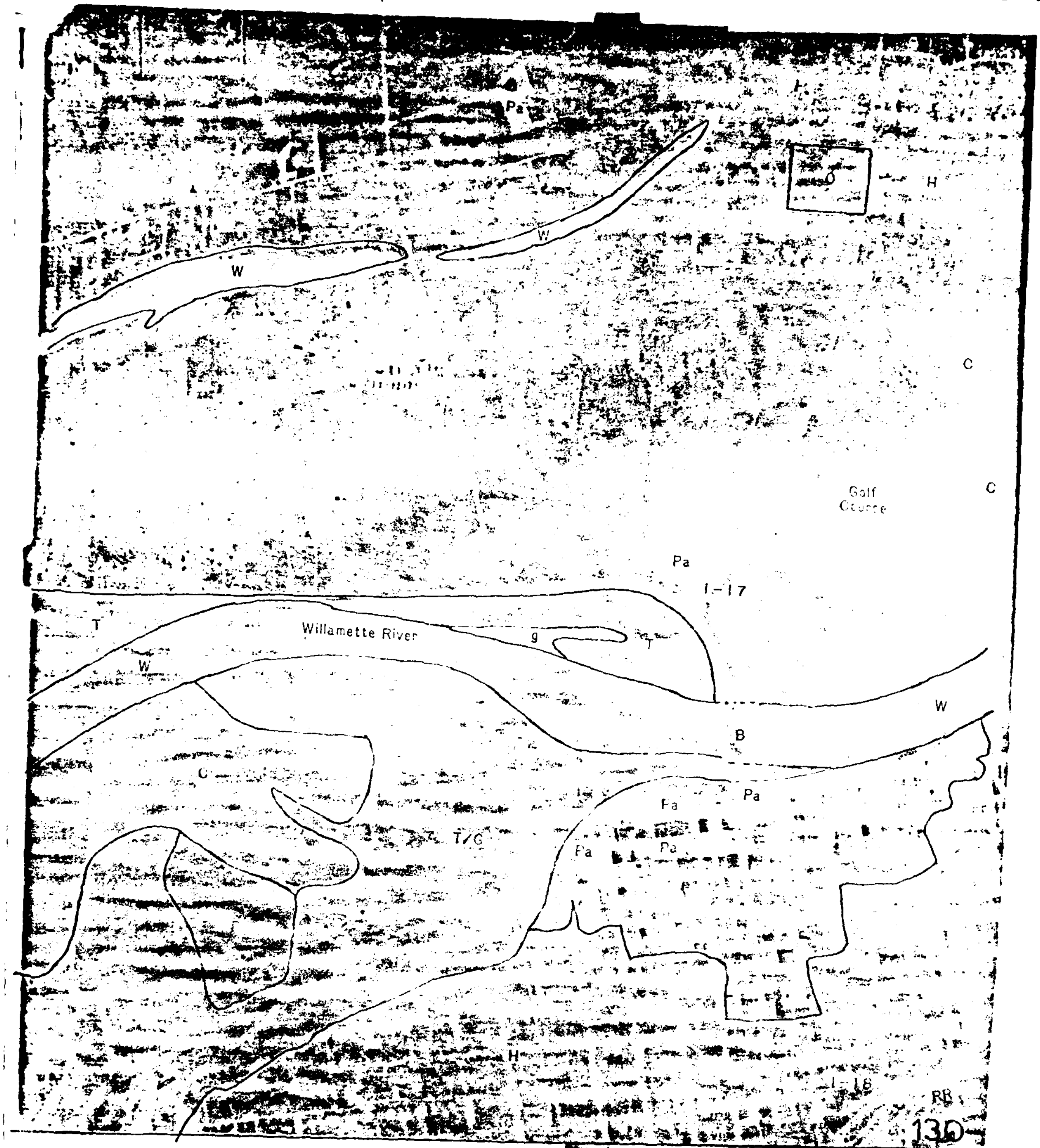
19 August 1980

Figure 2.12

N

LEGEND

C	Cropland	T/G	Trees and grass mixed
CI	Circular Irrigation	W	Water
O	Orchard	WI	Mill ponds
H	Residential	I	Commercial/Industrial
Hm	Motilehome	RR	Railroad Tracks
T	Trees		



North Albany Test Site

Thermal Infrared

19 August 1980

Figure 2.13

N

LEGEND

T/G	Trees and grass mixed	T	Trees
B	Bridge	g	Grass
H	Residential	I	Commercial/Industrial
RR	Railroad Tracks	O	Orchard
P	Bare soil	W	Water
C	Cropland	Pa	Asphalt Parking Area

Fulda Gap look-alike Test Site

Panchromatic

19 August 1980

Figure 2.14

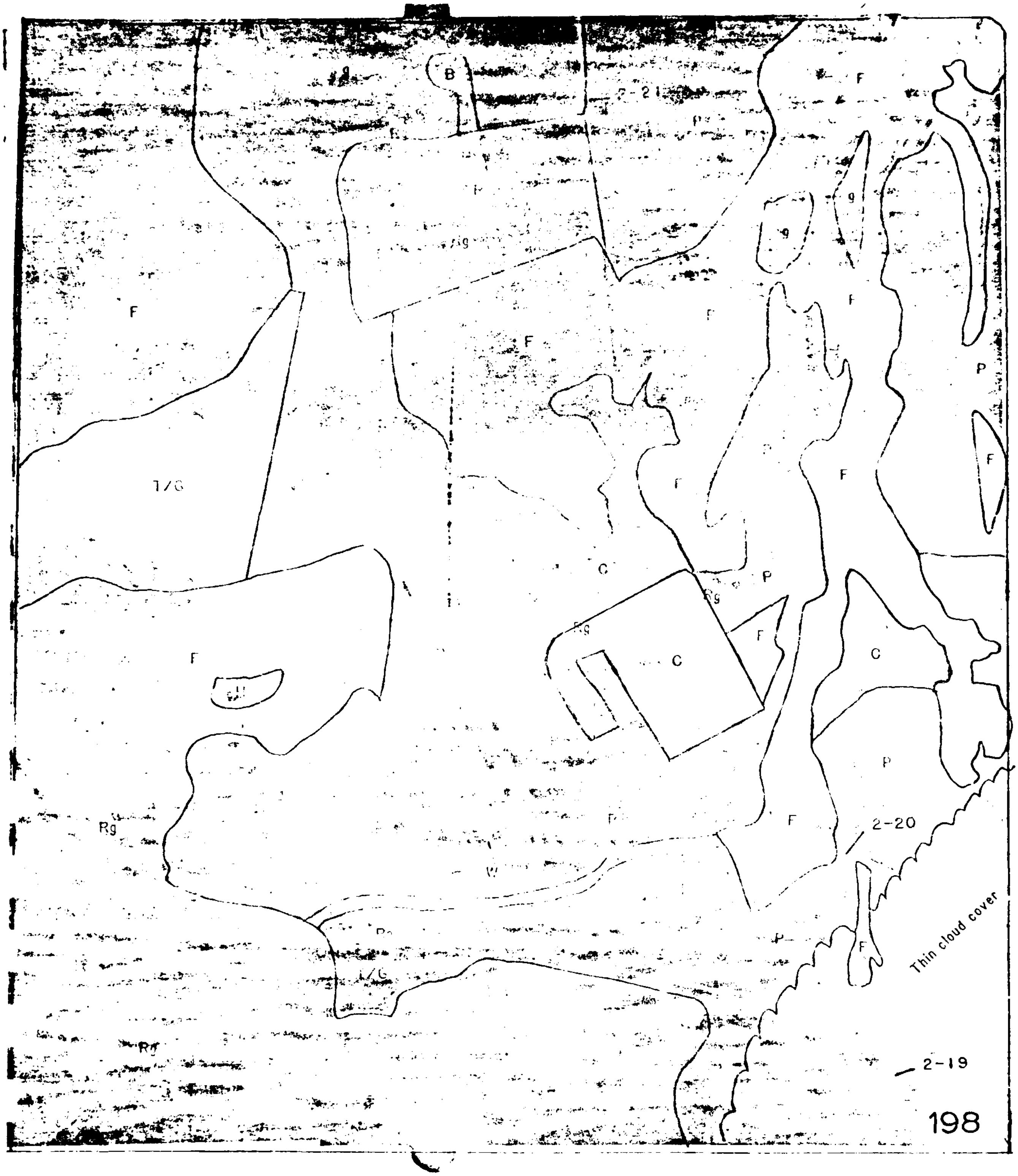
N

LEGEND

F	Forested Area	R	Rifle range	Ra	Asphalt Roads
H	Residential	B	Building	⚒	Open pit quarry
C	Cropland	Rg	Gravel Road		
W	Water	g	Grass		
P	Bare ground	T/G	Trees and grass mixed		

F	Forested areas	S	Radar shadow
Fm	Forested mountain	LD	Look direction
R	Rifle Range	g	Grass areas

Figure 2.17



Fulda Gap look-alike Test Site

Thermal Infrared

19 August 1980

Figure 2.18

N

LEGEND

C	Cropland	B	Building
W	Water	F	Forested area
R	Rifle Range	P	Bare ground
T/G	Trees and grasses mixed	g	Grass
H	Residential		
Rg	Gravel road		
Ra	Asphalt Road		

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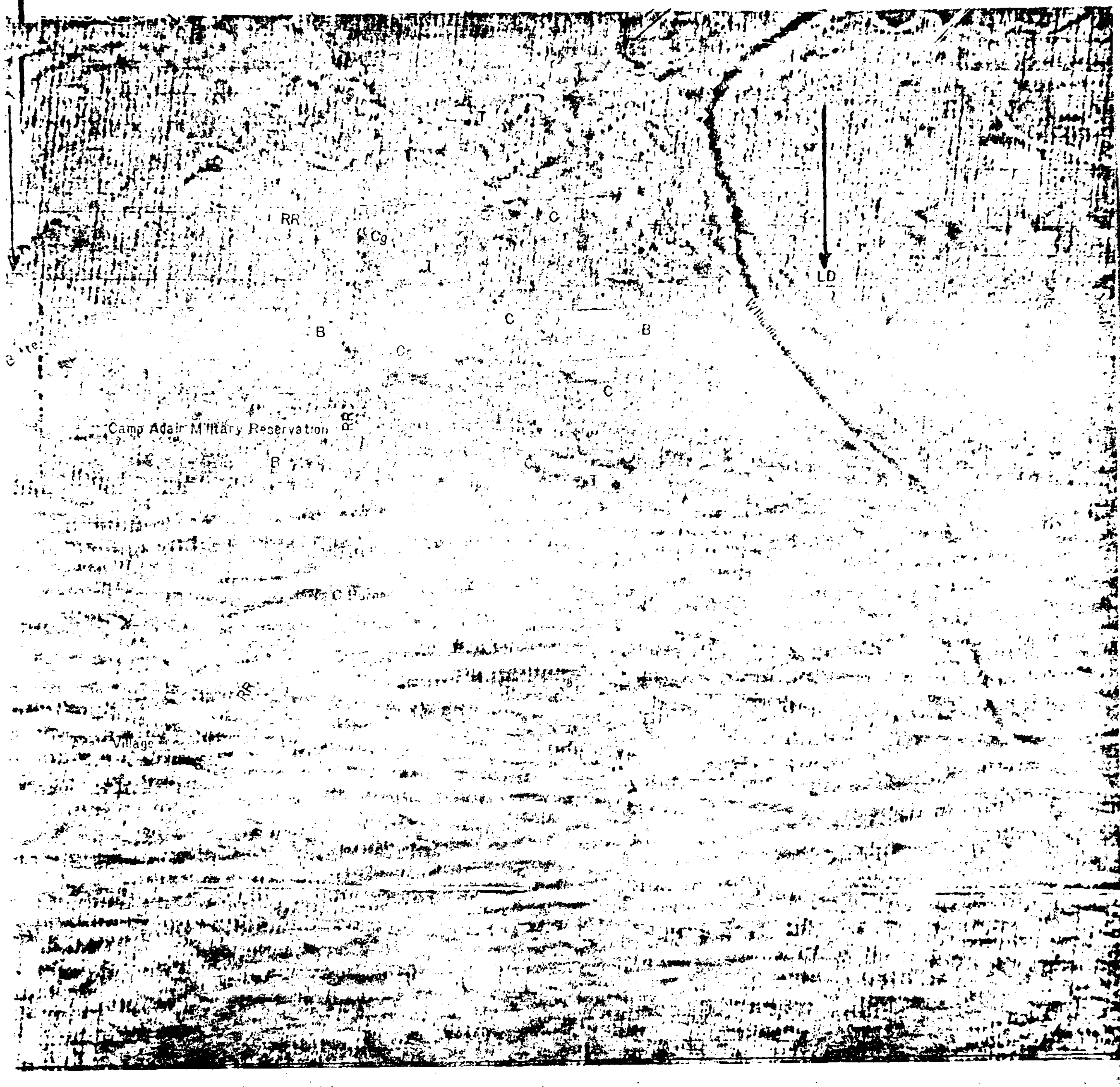
19 August 1980

Figure 2.19

F	Forested areas	P	Bare ground
C	Cropland , grain	g	Grasses
H	Residential areas	Cg	Cut grain
O	Orchards	B	Commercial building
W	Water	RR	Railroad tracks

⚒ Quarry



Camp Adair and Willamette River Test Sites

X– Band Radar

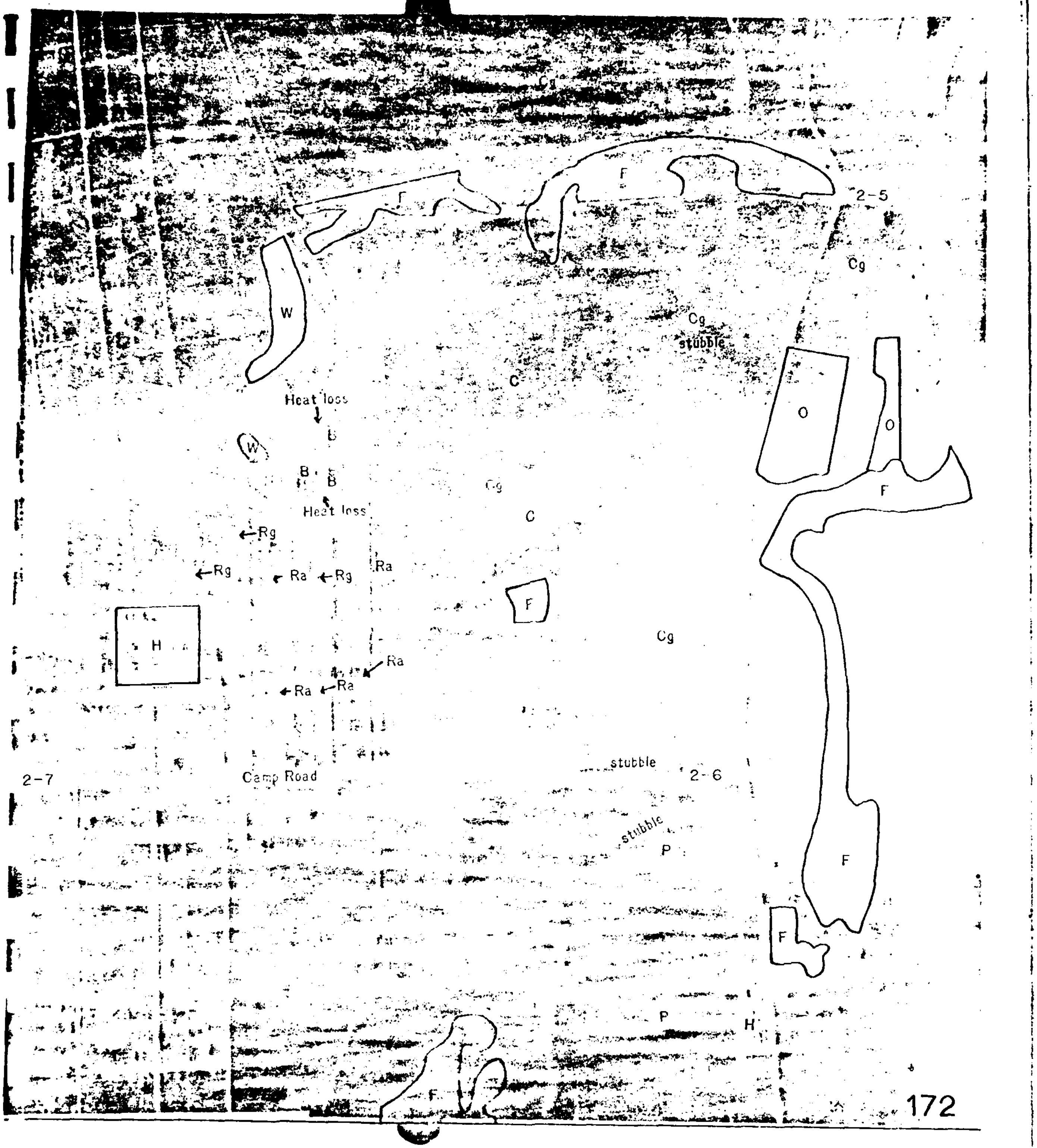
18 August 1980

Figure 2.21.

N

LEGEND

C	Croplands
Cg	Cut grain
T	Trees
LD	Look direction
RR	Railroad tracks



Camp Adair Test Site

Thermal Infrared

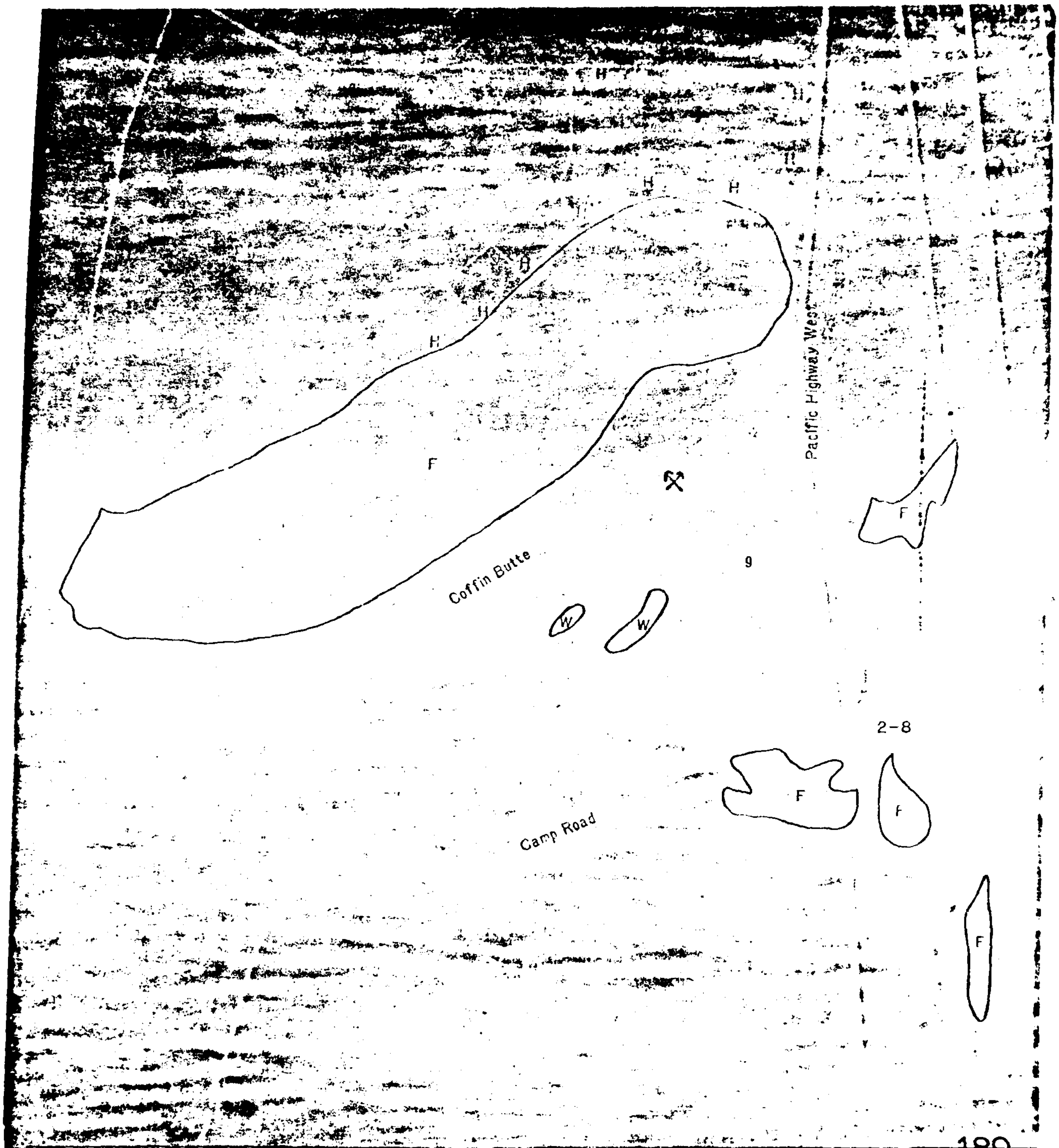
19 August 1980

Figure 2.22

N

LEGEND

B	Buildings	O	Orchard
C	Cropland, grain	P	Bare ground
Cg	Cut grain	Ra	Asphalt Road
H	Residential areas	Rg	Gravel roads
F	Forested area	W	Water



Camp Adair Test Site

Thermal Infrared

19 August 1980

Figure 2.23

N

LEGEND

H	Residential areas
F	Forested areas
W	Water
g	Grass
⚒	Quarry

Willamette River Test Site

Panchromatic

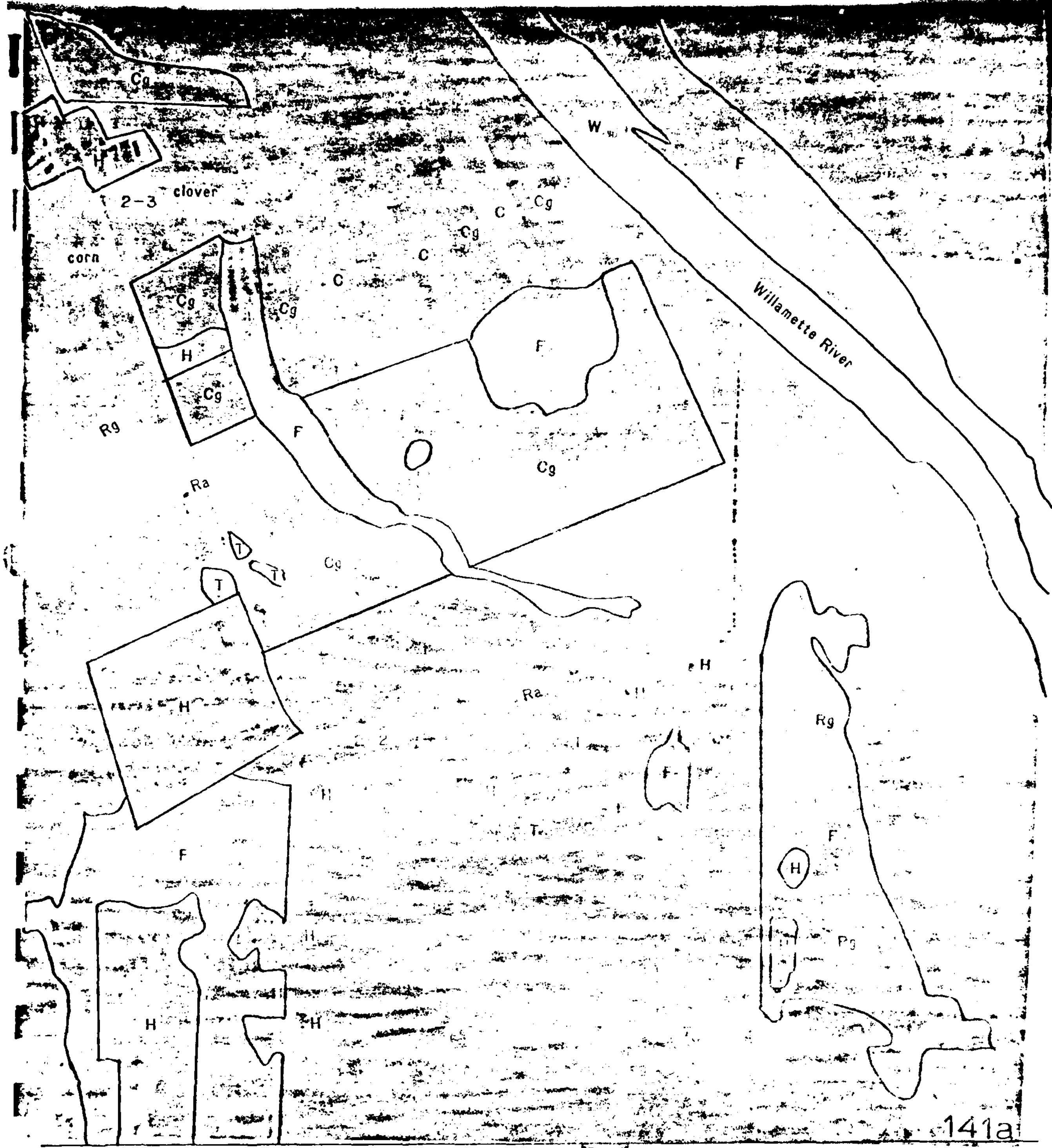
19 August 1980

N

Figure 2.24

LEGEND

C	Cropland, grain	R	Cut-off meanders	O	Orchards		
Cg	Cut grain	P	Fallow ground bare soil	r	Row crops		
F	Forested area	T/G	Trees and grass mixed	W	Water		
g	Grasses	Ra	Asphalt roads	T	Trees		
H	Residential areas	Rg	Gravel roads				



Willamette River Test Site

Thermal Infrared

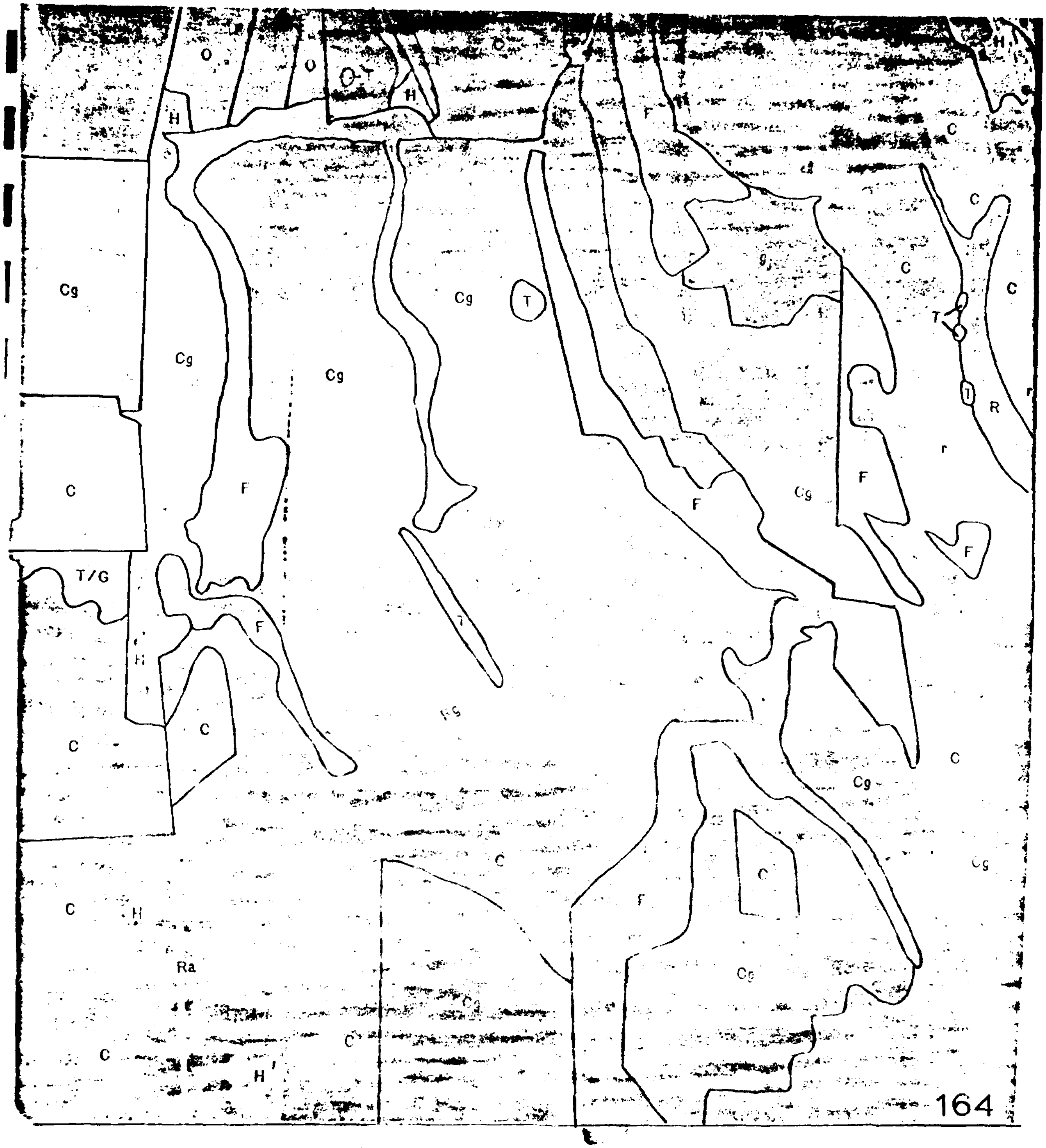
19 August 1980

Figure 2.26

N

LEGEND

C	Cropland, grain	P	Bare ground
Cg	Cut grain	W	Water
F	Forested areas	Ra	Asphalt road
H	Residential areas	Rg	Gravel road
T	Trees	r	Row crops



Willamette River Test Site

Thermal Infrared

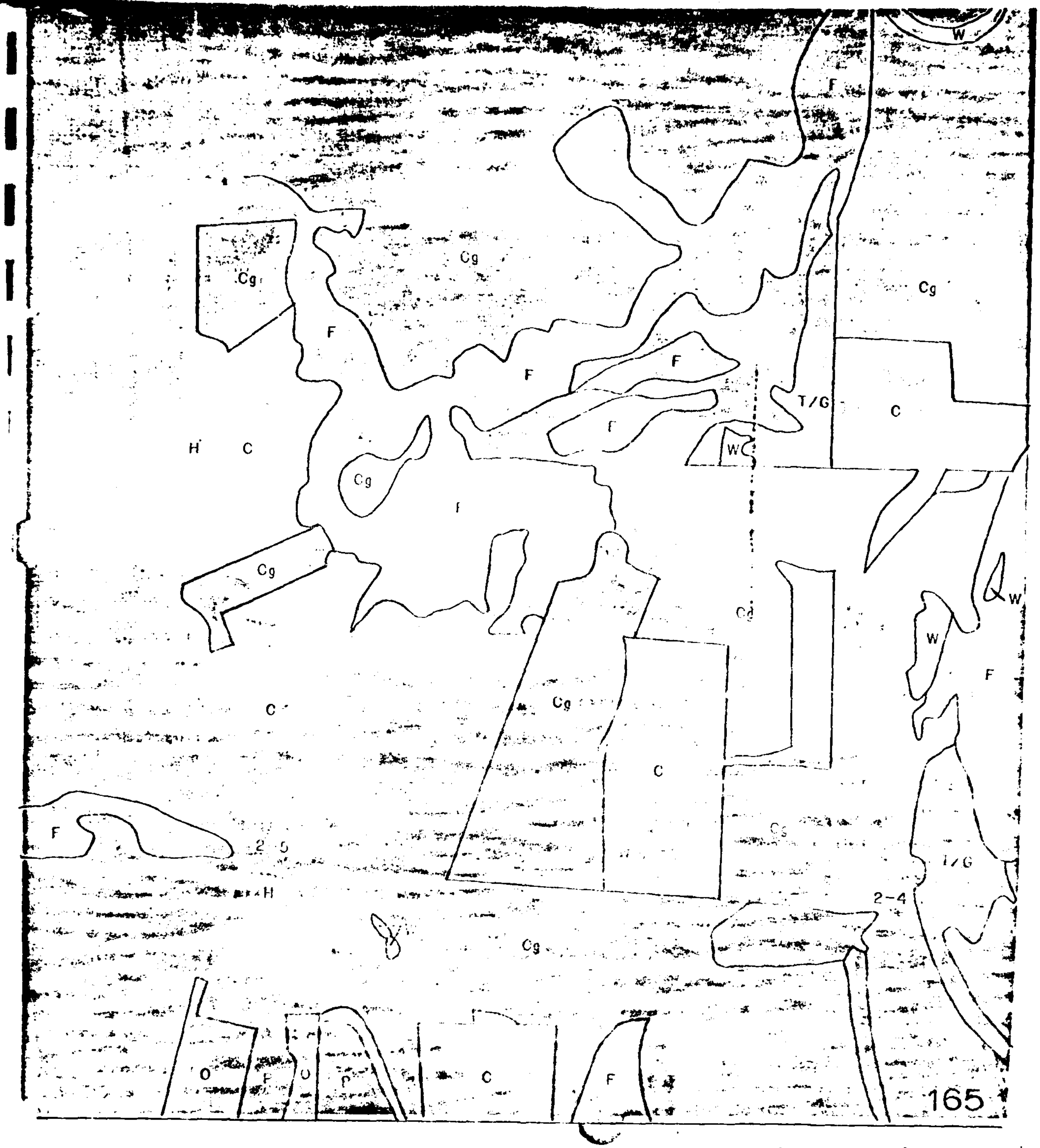
19 August 1980

Figure 2.27

N

LEGEND

C	Cropland, grain	T	Trees
Cg	Cut grain	Ra	Asphalt roads
F	Forested areas	Rg	Gravel roads
H	Residential areas	T/G	Trees and grass mixed
O	Orchards	R	Cut-off meanders
P	Bare ground	r	Row crops



Willamette River Test Site

Thermal Infrared

19 August 1980

Figure 2.28

N

LEGEND

C	Cropland	W	Water
O	Orchard	Rg	Gravel Roads
F	Forested areas	Ra	Asphalt Roads
H	Residential areas	Cg	Cut grain
T	Trees	P	Fallow ground

Willamette River at Buena Vista

Panchromatic

19 August 1980

Figure 2.29

N

Legend

C	Cropland and pasture	H	Houses or residential areas
O	Orchards	F	Ferry
b	burned fields	⊙	ground data collection site
T	Trees	sp	water sprinkler
W	Water body	St	recent stream deposits

Willamette River at Buena Vista

X Band Radar

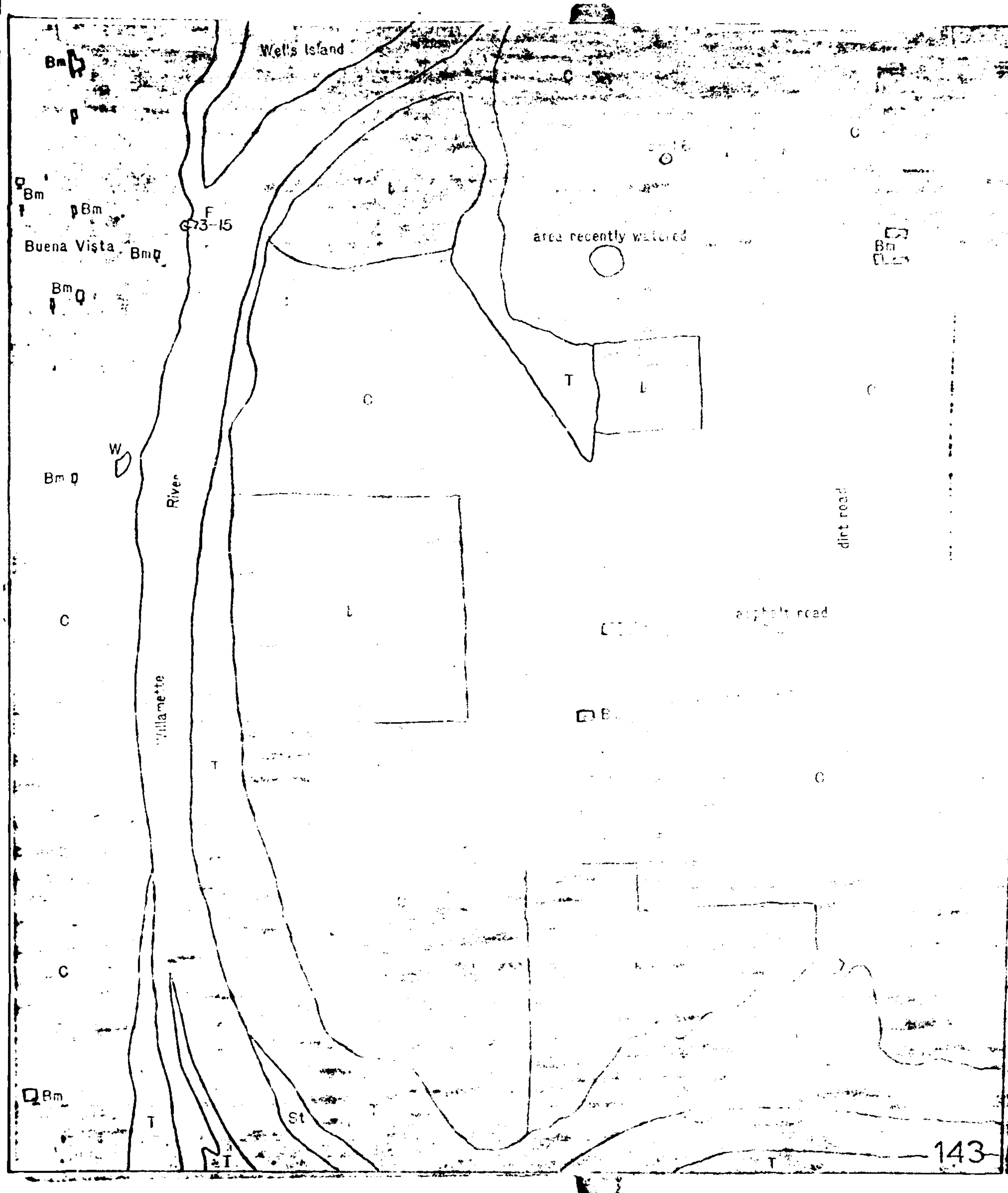
18 August 1980

Figure 2.32

N

Legend

C	Cropland and pasture	Bm	Building with metal roof
b	burned fields	O	Orchards
T	Trees		



Willamette River at Buena Vista

Thermal Infrared

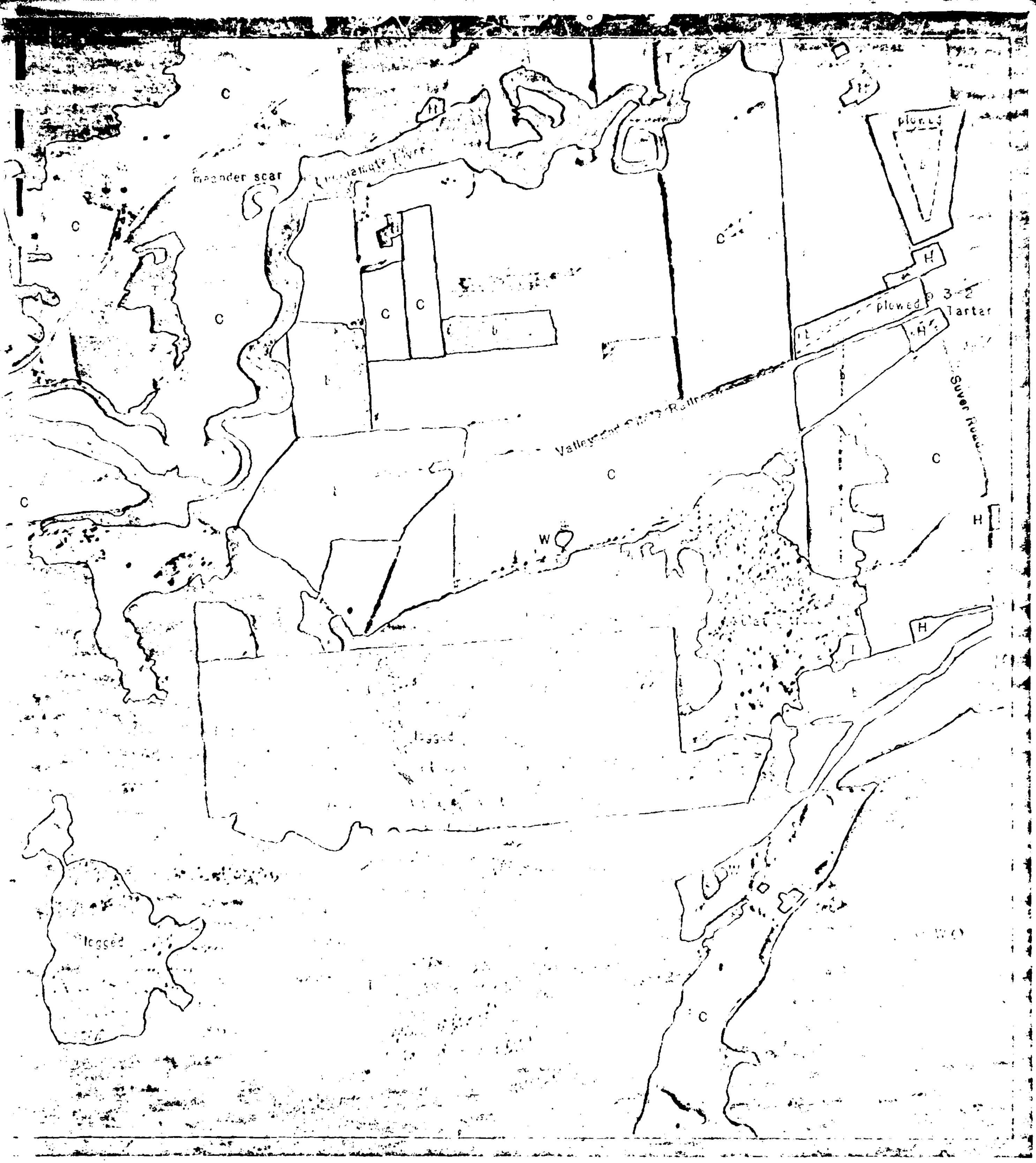
19 August 1980

Figure 2.33

Legend

N

C	Cropland and pasture	Bm	Building with metal roof
b	burned fields	⊙	ground data collection site
T	Trees	F	Ferry
W	Water body	St	recent stream deposits



Crossroads at Tartar

Panchromatic

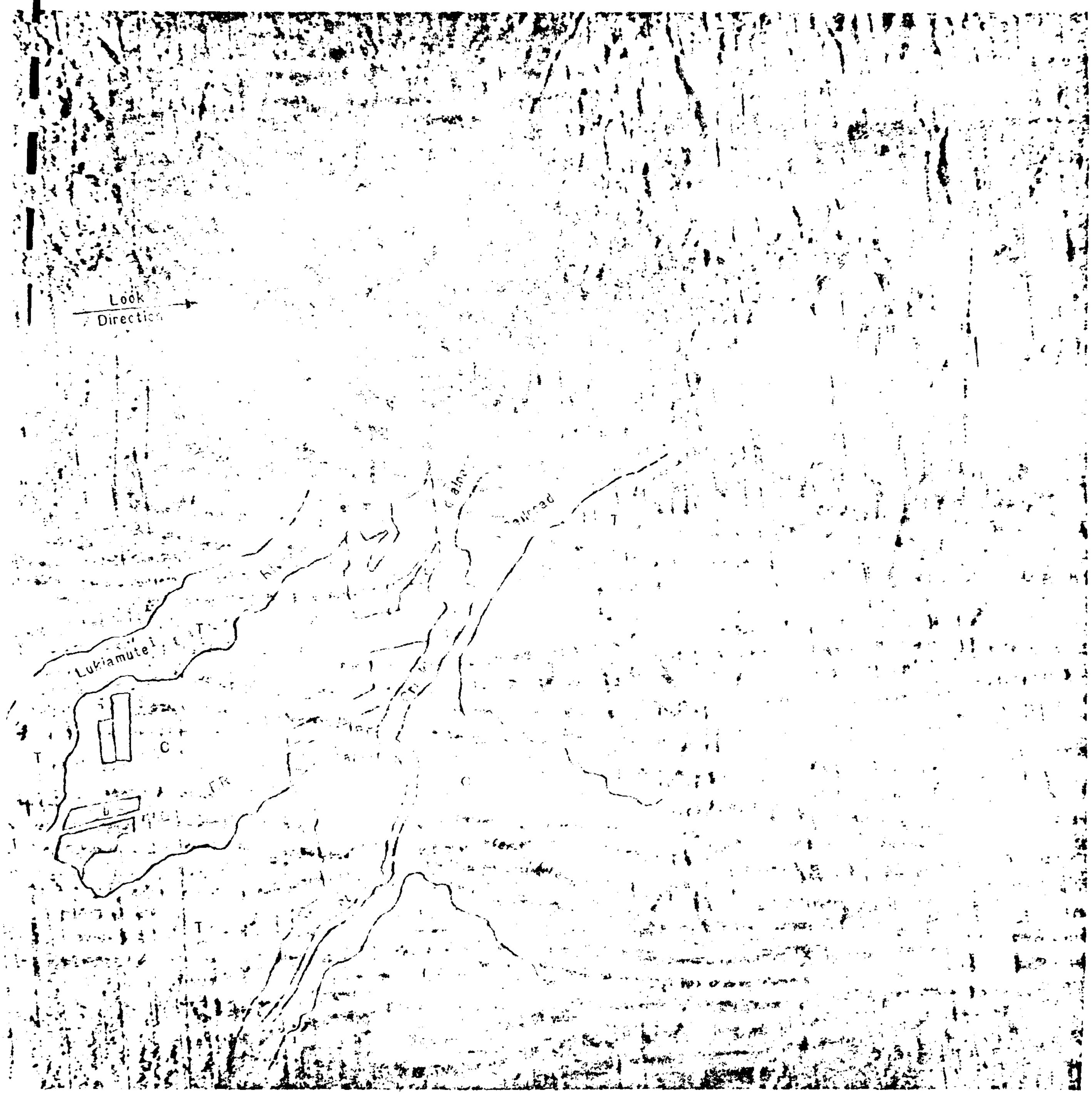
19 August 1980

N

Legend

C	Cropland and pasture	H	Houses or residential areas
b	burned fields	W	Water body
T	Trees	⊙	ground data collection site

Figure 2.34



Crossroads at Tartar

X Band Radar

18 August 1980

N

Legend

C Cropland and pasture

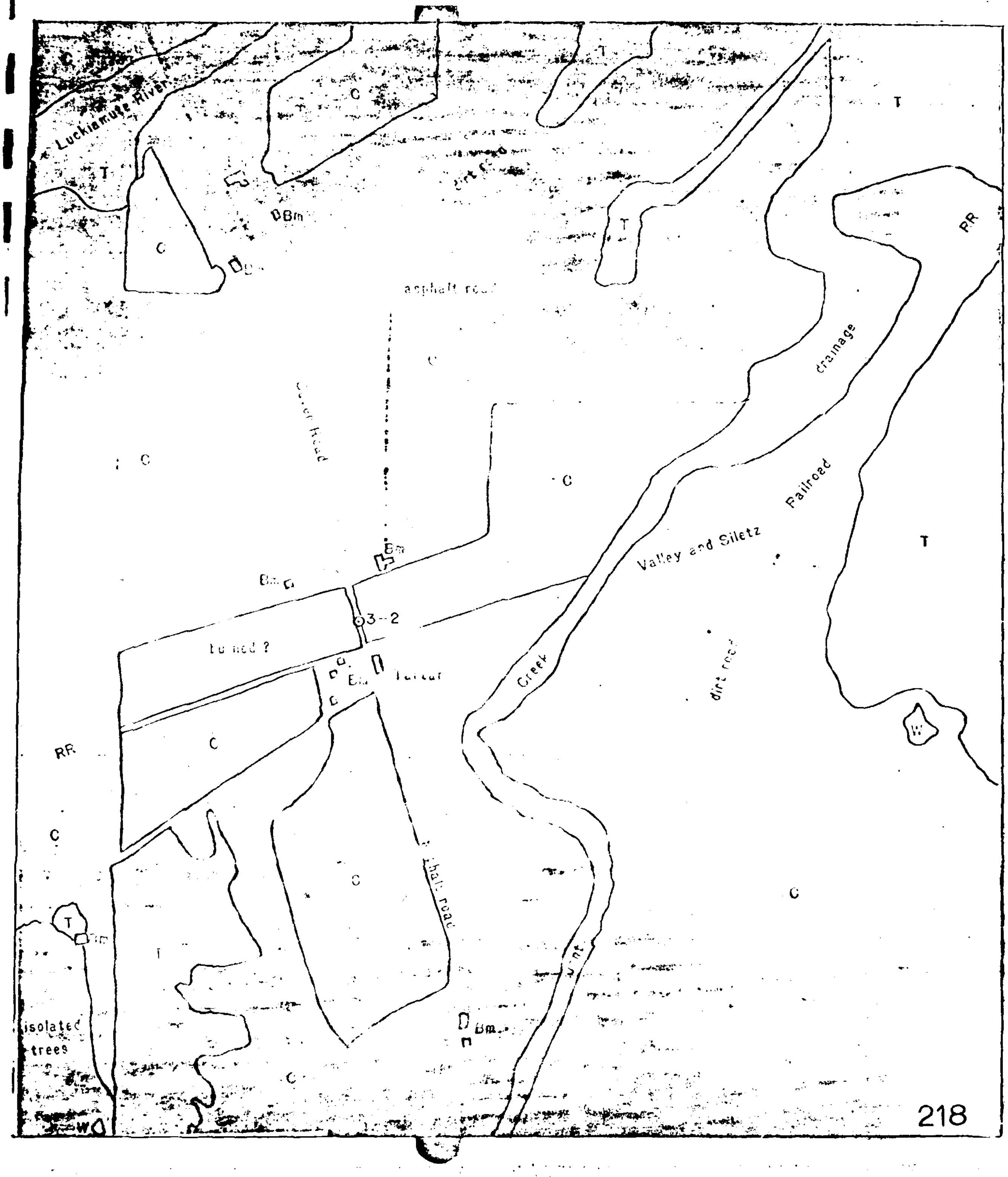
b burned fields

T Trees

Bm Building with metal roof

RR Railroad

Figure 2.36



Crossroads at Tartar

Thermal Infrared

19 August 1980

Figure 2.37

N

Legend

C	Cropland and pasture	Bm	Buildings with metal roofs
b	burned fields	⊙	ground data collection site
T	Trees	W	Water body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